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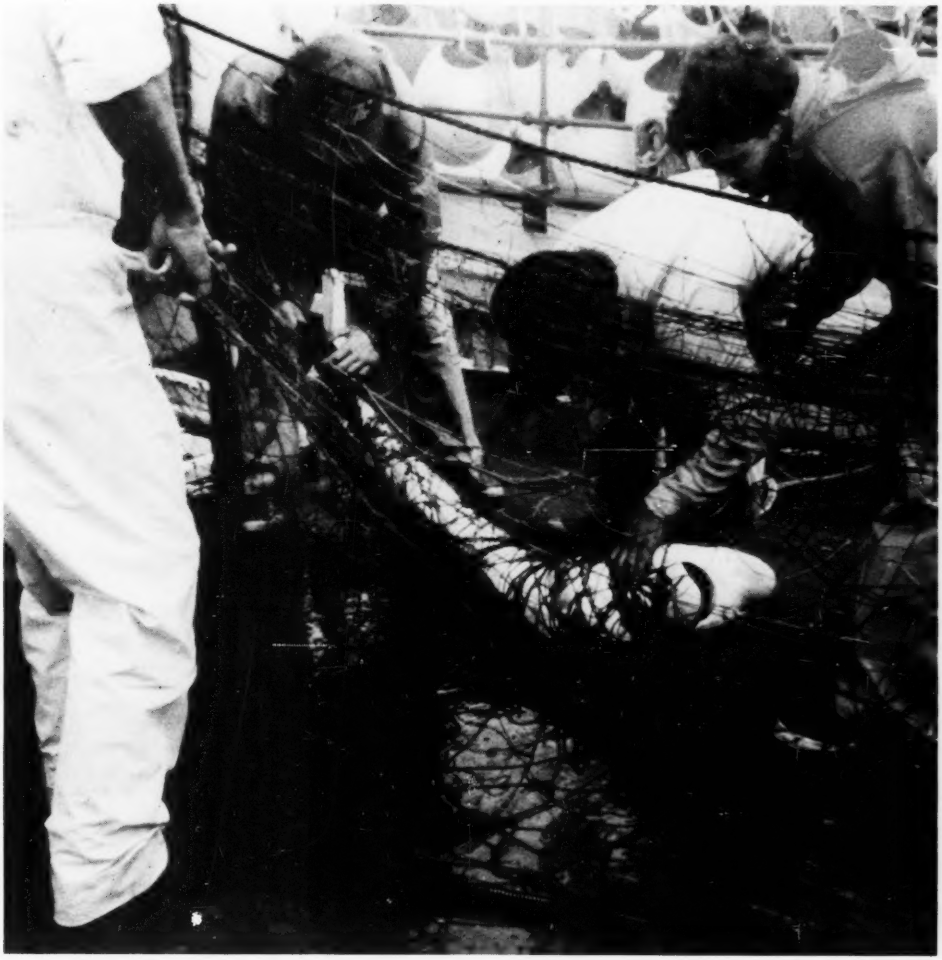

Shark Fisheries

Marine Fisheries
REVIEW

On the cover: Pacific
coast gillnet shark fishery
photograph courtesy of Dennis
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Review of U.S. West Coast Commercial Shark Fisheries

DAVID B. HOLTS

Introduction

Commercial fishing operations directed toward various shark species have, in the past, been relatively short lived. A few shark fisheries, such as that for the spiny dogfish, *Squalus acanthias*, have been sustained over long periods. These fisheries generally produced minimum ex-vessel prices and fluctuating yields in a market with uncertain demand. Aggressive small-vessel fisheries grew on the U.S. west coast as new markets offering high yields and profits developed for shark meat. Responding to the new demand, these new fleets began landing large quantities of sharks. Elasmobranch fisheries such as the well-documented soupfin shark, *Galeorhinus zyopterus*, fisheries in the early 1940's and the recent decline of the drift gillnet (DGN) fishery for thresher shark, *Alopius vulpinus*, and the setnet fishery for Pacific angel shark, *Squatina californica*, in southern California are examples.

ABSTRACT—The economic history of elasmobranch fisheries generally indicates the need for a high catch per unit of effort because of fluctuating commercial value and market demand. Growth and reproduction in most elasmobranch species are extremely slow, and as a result there is a close relationship between stock size and recruitment. Because of this relationship, only a small amount of that stock is available to support a sustained fishery. The increased demand for shark as a food fish has put tremendous fishing pressure on some species. Two of these, the common thresher, Alopias vulpinus, *and Pacific angel shark,* Squatina californica, *have not responded well to this increased pressure. Several other stocks appear healthy even though some warning signs of overfishing are appearing. The need for reduced fishing on some stocks and increased monitoring of catch for others is warranted.*

Although sharks are vulnerable to a wide variety of fishing gears, the primary reason they are not able to support high-yield fisheries is their apparent inability to respond to increased fishing pressure. Unlike teleosts, most elasmobranch species have a low rate of reproduction, slow growth, and relatively late maturity. Consequently, any rapid increase in fishing mortality can lower the rate of recruitment to a very low level. These facts are well documented (Ripley, 1946; Holden, 1973, 1974, 1977). When recruitment falls below the ability to respond to increased fishing pressure, that population will decline until fishing effort is reduced or the fishery collapses. Unfortunately, elasmobranchs are so vulnerable to overexploitation by expanding fisheries that long-term depletion problems may already exist before fishery managers are able to assess the problem with standard monitoring techniques and analysis. Notwithstanding the additional pressure from political and special interest groups, population declines for many of these stocks could continue for some time even if fishing effort were removed immediately.

Background

Before the 1970's various species of shark were used commercially in the United States for food, vitamin-rich liver oils, pet food, leather, as curios, and for reduction to protein and fertilizer. These products did not generate much demand and only commanded mediocre market prices. Shark demand as a food fish began to increase on the west coast during the middle-1970's. Consumer response to this high protein, low fat meat was very good, and shark was finally accepted as a nutritious and flavorful alternative to red meat and the more traditional seafoods as well.

Ex-vessel prices for shark meat rose sharply in response to this consumer demand and several species of shark became important west coast fisheries. Thresher shark prices, for example, increased 500 percent between 1977 and 1986. West coast fish buyers paid increased prices for dressed Pacific angel, soupfin, and shortfin mako, *Isurus oxyrinchus*, shark (called bonito shark locally). They were also test marketing white shark, *Charcharodon carcharias*; salmon shark, *Lamna ditropis*; sevengill shark, *Notorynchus maculatus*; leopard shark, *Triakis semifasciata*; spiny dogfish, and other shark species as well. Markets that formally sold shark only as "grayfish," now advertised fresh shark at retail prices as high as $4 and $5 per pound. Commercial buyers were shipping fresh shark meat throughout the nation, and many prestigious restaurants featured shark meat in their specials and as the catch of the day. The growth in reported landings along the U.S. west coast over the past 12 years is shown in Table 1.

The tremendous success of these shark fisheries raised concerns that some stocks

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Table 1.—Commercial U.S. west coast and Mexican shark landings, 1974-86.

Species	1986[1]	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975	1974
Pacific angel	1,139,250	1,237,810	633,250	351,344	317,953	260,031	110,022	123,652	82,383	366	690	2,967	179
Bigeye thresher	46,184	119,632	74,769	106,507	36,269	10,542	10,842						
Blue	2,850	2,356	3,940	13,983	57,838	202,898	192,130	83,966	35,904	98,365	9,928	497	46
Bonito	456,063	215,126	244,021	322,953	527,677	275,830	155,336	35,334	27,436	19,911	2,293	9,958	4,032
Brown smoothhound	13,506	33,312	8,091	14,101	5,263	23,641	5,783	2,440	7,365	264	20	20,000	150
Common thresher	1,215,165	1,528,766	1,662,587	1,757,353	2,386,585	1,937,618	1,806,002	735,602	302,073	129,522	46,887	37,729	2,225
Cow	439	427	1,333	1,258	1,328	771	438	290	249		35		
Dusky				120		196			103	202	50		
Gray smoothound	506	1,874	6,846	1,055	2,520		761	12,046	33,745				
Horn	197	363	613	485	7,541	2,286	8,465	21,055	273	1,156	60		
Leopard	65,826	75,695	69,187	101,309	70,666	49,380	40,085	26,966	34,956	22,267	14,590	10,831	5,918
Pelagic thresher	237	640		10,923									
Salmon	2,252	2,016		230	996					77			
Sevengill	55	893	282	1,735	2,041	3,415	545		84				
Sixgill		4	96	128		317	12	20					
Smooth hammerhead	3,628	3,920	6,831	44,481	1,866	2,259		304	1,025	1,860			
Soupfin	197,164	243,661	558,280	176,155	249,070	257,348	192,119	221,840	176,070	162,166	182,390	85,430	42,017
Spiny dogfish	9,061	2,837,927	7,649,393	5,398,532	4,591,551	4,831,846	7,141,280	9,445,000	6,522,003	5,813,147	22,697	179	868
Swell		20	222				163		2,795				
Unspecified	135,146	193,317	178,213	181,373	273,721	580,932	1,158,219	840,956	600,473	563,382	582,450	365,849	174,523
White	923	2,861	6,102	634	8,052	42	1,660	2,269					
U.S. total	3,449,340	6,500,620	11,107,244	8,481,489	8,541,837	8,439,352	10,823,862	11,551,740	7,826,837	6,812,685	862,090	533,440	229,958
Mexico-Japan data			72,767	729,878	421,169	319,118	41,896						
Grand total	3,449,340	6,500,620	11,180,011	9,211,367	8,963,006	8,758,470	10,865,758	11,551,740	7,826,837	6,812,685	862,090	533,440	229,958

[1]Preliminary data.

probably could not sustain directed fishing pressure. This was particularly evident for the rapidly expanding effort directed at southern California thresher and angel shark fisheries. Complicating matters was the fact that little information necessary for management purposes was known about many of these species. Some basic life history information was known, or inferred, from related species, but few data on stock size, distribution and range, migratory behavior, age at maturity, fecundity, and mortality were available for most of the shark species undergoing increased exploitation. Additionally, the techniques for aging elasmobranchs were not worked out for most species, although some progress was being made (Cailliet et al., 1983).

In this paper, I review the current status of some of the more important shark fisheries along the west coast of the United States. Landings, fishing effort, and related biological and life history information are discussed for each species taken in these fisheries. Shark fisheries from Alaska and Canada (except British Columbia's spiny dogfish catch) have not been included in this review. General life history information included in the descriptions is summarized from Castro (1983) and Compagno (1984).

Thresher Shark Fishery

The fishery for thresher sharks is centered off southern California, between San Diego and the Mendocino Escarpment, north and offshore of San Francisco. Three species, the common thresher, *Alopias vulpinus*, the bigeye thresher, *A. superciliosus*, and the pelagic thresher, *A. pelagicus*, are caught in the fishery, although the common thresher is the principal species.

All three forms are considered highly migratory throughout the warm and temperate areas of the oceans. They feed on squid and small schooling fishes, including clupeoids, scombroids, and several types of bottomfish. Fishermen have recently reported common threshers taking significant numbers of salmon off the coasts of Oregon and Washington, although this has not been described as a major prey species of the thresher. Although there are some differences in feeding behavior, all three forms are known to use their long tail to stun their prey before eating them. Neither the magnitude of the population nor the distribution of individual stocks is known. Stock structure is unknown and differences in size at maturity and number of offspring suggest that Pacific common threshers may be isolated from those in the Indian Ocean.

All three species are ovoviviparous. Females produce one litter each spring and mating occurs later that summer. Gestation lasts about 9 months. Litters usually consist of two, four, or six fully formed pups weighing 5-6 kg (12 pounds) each. Using x-radiography to delineate the circuli on 143 common threshers collected off California, Cailliet and Bedford (1983), prepared a von Bertalanffy growth curve. The growth curve indicated that females mature at about age 7 (390 cm total length), and males mature at about 5 years or about 333 cm. The sex ratio of common threshers from this population appears to be nearly equal, although sexually segregated schools do occur. Estimates of natural mortality are assumed to be low since pups are born fully formed and both

the growth and reproduction rates are low.

The fishery began as a minor operation with only about 15 vessels landing sharks primarily as a by-catch during more lucrative fishing operations. The growth of the fishery was also stimulated by the valuable take of swordfish, *Xiphias gladius*, and a favorable ruling by the California Fish and Game Commission (CFGC) to allow drift gillnet boats to land and sell swordfish. The ex-vessel price for common thresher increased from $0.29/pound in 1977 to $0.73/pound in 1980 and reached $1.60/pound in 1986. The fleet grew to over 200 vessels by 1980, and entry into the fishery became limited by law (Bedford and Hagerman, 1983). Swordfish was now the primary target of the California DGN fleet. By 1985 the number of licensed vessels totaled 227 with another 33 vessels holding permits to fish only north of Point Arguello, Calif.

During the spring, the common thresher is the primary target of this fishery in the northern area. The bigeye thresher is also commonly landed. Bigeye threshers have soft-textured meat that tends to shrink while cooking and has met with only moderate success in the fresh-fish markets. Landings have increased in recent years due to better handling methods. The pelagic thresher is rarely taken in the catch because of its soft and bitter tasting meat and low abundance in productive fishing areas.

Off southern California, highest catch rates occur in the spring. Fishing effort shifts to swordfish during the summer and fall months. Common threshers move into the Southern California Bight in the early spring for pupping and breeding. Large threshers appear to follow the warmwater isotherms northward into central and northern California areas, and good catches have been taken through August. Fishable stocks appear to be limited to within about 75 n.mi. of shore, islands, seamounts, or shallow banks. The southern extension of the population is unknown because U.S. commercial fishing boats are not permitted within the Mexican Fishery Conservation Zone. Mexican-Japanese joint ventures have operated long-line vessels off Baja California for many years. Although their primary targets are tunas and billfishes, substantial amounts of common and bigeye thresher sharks are reportedly landed. Catch statistics are not available for either species.

Prior to 1986, landings north of the Mendocino Escarpment were few. The 1982 and 1983 seasons were affected by a strong El Niño that caused warm waters to extend further north than normal. This warming condition may have caused a shift in the population centers of both the common and pelagic forms to the north. Oregon and Washington issued 3 experimental gillnet permits for thresher sharks in 1983 and 34 in 1984. Initial catches in 1983 indicated availability of fish outside southern California and possible expansion of the fishery. Most common threshers taken in 1983 were caught off central California, while bigeye and pelagic threshers were caught off southern California. Large catches in 1985 continued off central and southern California under normal conditions.

CFGC regulations implemented in 1986 were designed to reduce fishing mortality on the thresher shark populations. Already a limited entry fishery, these additional regulations included time and area closures, reduced the number of fishing days per season, and implemented new gear restrictions to 75 miles offshore. California vessels landed 380,390 pounds of common thresher and 38,079 pounds of bigeye thresher shark in this 30-day opening. At the end of this period, the fishery shifted to the north. Operating with experimental fishing permits these vessels produced good catches of common thresher off Oregon and Washington (Table 2). Under these permits (57 to Washington and 35 to Oregon) Oregon received 454,748 pounds from 33 vessels and 21 vessels landed 200,000 pounds in Washington's coastal ports. An additional 173,000 pounds were landed in California during the 1986 swordfish season.

The dressed weight of fish taken in these northern ports was in excess of 210 pounds, compared with the average of only 40 pounds for those taken off southern California. The sex ratio for these threshers was nearly even off California but catches off Oregon and Washington were mostly large males (Brian Culver, Wash. Dep. Fish. Personal commun., March 1986).

Although considered highly migratory, catch data indicate common threshers may have local population centers that move along the coast in relation to various environmental conditions. A tagging program to describe these movements is currently being conducted by the California Department of Fish and Game (CDFG), although results are not yet available. There is evidence in the literature (Compagno, 1984) of sexually segregated movements, and landing receipts of the current west coast fishery indicate threshers caught off Oregon and Washington were nearly all adult male. Such movements in other shark species tend to occur near the range limits of the population. This information along with the ap-

Table 2.—Landings in the U.S. west coast thresher shark fishery, 1977-86.

	California			Oregon		Washington		Total landings	
	No. of	Weight							
Year	receipts	Common	Bigeye	Receipts	Weight	Receipts	Weight	Pounds	Metric tons
1977	349	129,522						129,522	59
1978	433	302,054						302,054	137
1979	745	735,536						735,536	334
1980	880	1,806,002	10,842					1,816,844	824
1981	1,632	1,974,037	10,542					1,984,579	900
1982	1,851	2,386,585	36,269					2,422,854	1099
1983	2,604	1,707,256	68,010	1	1,155	4	24,471	1,800,892	817
1984	2,691	1,657,693	74,770	0		8	6,271	1,738,734	789
1985	2,153	1,528,766	119,632	0		0		1,648,398	748
1986[1]		545,417	46,184		454,748		200,000	1,200,050	545

[1]Preliminary.

parent shift of population centers during the 1982-1983 El Niño event suggests that this population, as a fishery stock, is not widely distributed but may be more geographically limited than previously thought.

Common thresher landings in California peaked in 1982 and they have declined since. Catch per unit of effort (CPUE) has decreased since the 1982 season (Bedford, 1985). Further evidence that the stocks are not able to support the current level of exploitation comes from the length-frequency data collected by the CDFG. These data show a steady decline in total length from 1981 to the present and that the number of subadult threshers has been significantly reduced off California. The catch off Oregon and Washington is dominated by large adults and has not included subadults to any extent.

From available evidence it is clear that the local thresher shark population is not large and that immigration from adjacent waters is not sufficient to sustain the current fishing pressure. This was first speculated by Hanan (1984). The fishery has been in a steady decline since 1983 and the CDFG has decided that "the California drift gill net shark fishery may be in precarious condition" (Bedford, 1985); the causes of that condition are discussed by Bedford (1987).

Pacific Angel Shark Fishery

The fishery for the Pacific angel shark, *Squatina californica*, started in 1978 as an offshoot of the very successful Pacific halibut, *Hippoglossus stenolepis*, setnet fishery near Santa Barbara, Calif. This fishery is currently undergoing tremendous growth similar to that of the local thresher shark fishery. This small- to medium-sized, bottom dwelling shark is reported to occur in shallow coastal waters from Alaska to Baja California. It is the only species of the family Squatinidae in the north Pacific and is reported to be extremely abundant around Santa Barbara and the California Channel Islands.

The angel shark is a nocturnal fish, foraging at night for bottom and epibenthic fishes and squid. It is relatively inactive during the day, resting on the bottom sand or mud with only its eyes and back exposed. Angel sharks tagged with ultrasonic transmitters at Santa Catalina Island (Isthmus Cove) exhibited maximum activity periods at dusk and at midnight (Standora and Nelson, 1978). Tagging also showed that angel sharks have a home range and will return to the same general area after a night of foraging. More recent tag return data further support the home range concept, but also indicate that some angel sharks circumnavigate the local islands and can move across the Santa Barbara Channel from the mainland to the Channel Islands (John Richards, Sea Grant Marine Adviser, Goleta, Calif. Personal commun., Feb. 1986). Seasonal changes in the population centers have not been shown in the local areas, although Standora and Nelson (1978) suggest that angel sharks are more plentiful in June and July than in the winter months.

The life history and distribution of the angel shark may be the least known of any of the sharks supporting a major west coast fishery. Reproduction is ovoviviparous, but has not been described in the literature for this species. Both male and female angel sharks mature at about 90 to 100 cm. Females have a gestation period of 10 months and bear an average of six fully formed young per litter, each averaging 255 mm long (Natanson 1984). Parturition occurs from March through June, followed by mating. Determination of growth rates and age has so far been impossible with standard methods. Angel sharks are born with 6-7 growth bands in their vertebrae, and apparently one or more growth bands are laid per year in a manner not fully understood. Natanson (1984) believes the rate of band deposition is related to somatic growth rather than annual, seasonal, or lunar cycles. The whole process may be complicated by major physiological events and possibly prolonged gestation (Cailliet et al., 1983).

The fishery began expanding after initial development and marketing problems were worked out in 1976. The major portion of this fishery occurs in and around Santa Barbara and the Channel Islands. The greatest catch is taken in waters <20 m deep and within 1 mile from shore (Collins et al., 1984; Collins et al., 1985). The angel shark fishery has not spread north of Point Conception and only incidental landings have occurred in Oregon and Washington. Prior to 1982 only 6-8 California vessels fished for angel sharks. Fishing effort increased in 1982 as the El Niño caused the northern displacement of other preferred species. California landings jumped to 317,000 pounds in 1982, doubled by 1984, and reached 1.3 million pounds in 1985. Exvessel prices paid to fishermen rose from $0.15/pound in 1978 to $0.45 in 1984. Landings of 1.1 million pounds in 1986 marked the first decline in catch since the fishery began expanding.

The CPUE estimates are only preliminary at this time but do not appear to be decreasing. The length-frequency of observed catch has just begun to show signs of decreasing. The future of this fishery is very much in question. There are no published growth rates or longevity estimates for this species. Little is known of the angel shark's distribution north or south of the Channel Islands where fishing pressure is greatest. There is no information to suggest that fishable quantities of angel sharks exist very far to the north or south of the Channel Islands or that immigration from surrounding areas is occurring. The few facts that are known suggest angel sharks are vulnerable to directed fisheries.

Currently there are no regulations for the angel shark fishery other than general state and county regulations for all set net use. The CDFG has proposed new regulations that will limit the size and style of nets used, times and areas fished, and size limits for small fish. This fishery warrants close scrutiny and possible precautionary action to forestall what some fishery biologists see as an almost unavoidable overexploitation of the local angel shark population.

Shortfin Mako or Bonito Shark Fishery

The shortfin mako, *Isurus oxyrinchus*, is known locally as the bonito shark. It is taken as a welcome by-catch by California drift gillnet vessels. Like several members of the family Lamnidae, the bonito shark is found in all tropical and

temperate oceans and in both coastal and open ocean habitats. They are highly migratory and are considered one of the fastest and most active predators. Both adults and juveniles are abundant off California and Baja California in the summer months.

Reproduction is ovoviviparous with 2-10 pups per litter. Gestation is about 1 year, with parturition occurring in late spring. Pratt and Casey (1983) used silver nitrate to delineate the circuli in the vertebra to construct a von Bertalanffy growth curve for 109 Atlantic-caught shortfin mako sharks. They determined that the age of maturity was 2 years for males and 6 years for females. The growth rate of males and females was similar although females grew larger. There are no mortality estimates (natural or fishing) for this species. The size in the catch is small (the average is 9-14 kg, dressed), but the length-frequency profile has not declined. Few landings have been reported north of California (only 10 percent in 1983 and none in 1984).

The bonito shark has good quality meat and is the object of long-line fisheries throughout the world. The California catch is almost entirely composed of juveniles taken in the drift gill net fishery for thresher sharks and swordfish. These small bonito sharks bring a wholesale price of $0.75-$1.25/pound.

Many southern California anglers consider the bonito shark a prime game fish because the fish fights and jumps when hooked. Shark derbies have become increasingly popular in recent years and if the trend continues, these catches may contribute significantly to overall landings.

Catch rates, length frequency, and estimates of CPUE provide little information on the magnitude, structure or distribution of the bonito shark stock(s). Estimates of CPUE are not reliable because the bonito shark is an incidental rather than a target species. Catch rates increased dramatically in 1980, peaked in 1982, and declined over the following three seasons. Although this decline in catch may indicate the first signs of overfishing, it may also have been caused by a change in fishing strategy aimed at thresher sharks or even a result of a population shift brought on by the 1982 El Niño. Landings were back to normal in 1986, length-frequency data have not changed, and there is no evidence that this stock has been significantly altered by current fishing pressure.

This fishery should continue to be monitored until there are sufficient data to assess the strength of the stock(s). Declines could occur if increased fishing effort were directed at the bonito shark, especially adults, or if stocks are smaller than expected.

Soupfin Shark Fishery

The soupfin shark, *Galeorhinus galeus*, has a long history of involvement in commercial fisheries. In addition to the west coast fishery, the soupfin (also called the school shark and tope shark) is fished in the southwest Atlantic, off South Africa, and off the southern coast of Australia. This species supported the large and well publicized fishery off California (and South Africa) in the late 1930's and early 1940's. Those fisheries focused on the vitamin-rich liver oil of the soupfin but collapsed due to overfishing and the advent of synthetic vitamin A developed during World War II.

In the eastern Pacific Ocean the soupfin shark is found in the temperate continental and insular waters north and south of the equator. It is an active, coastal-pelagic shark found from the surf line, shallow bays, and submarine canyons to depths near 500 m in some offshore areas. It is highly migratory and travels in small schools. This species exhibits marked sexual segregation, with adult males favoring the northern range, although in central California there are equal proportions of males and females. Major pupping areas are south of Point Conception. The current fishery is centered off southern California, with moderate production in Oregon and Washington.

Reproduction is ovoviviparous with one litter of 6-52 pups per year. Mating occurs in the spring with gestation lasting 12 months. Pups average about 35 cm at birth. Size at maturity for females is about 130-185 cm with maximum size to 195 cm. Males mature at 120-170 cm and reach a maximum of 175 cm. Females mature at about 11 years and males mature at 8 years of age. Growth of the California soupfin was described by Ripley (1946) from data collected during the early fishery.

The flesh of the soupfin provides an excellent market product. A small west coast fishery persisted until the late 1970's when other shark meat became popular. Both the commercial and sport fishery for soupfin shark is currently expanding off our west coast, with annual production in excess of 100 metric tons.

There is little current information concerning the structure of the west coast soupfin population. Holden (1977) estimated the unexploited, north Pacific stock at 29,000 tons. It is unlikely that population levels have returned to these pre-War levels, although there are no current mortality estimates. The southern distribution of the fishery stock extends well into Mexico, but catch records are not available from the Mexican fisheries.

The California fishery is centered off San Diego and Orange Counties. Commercial soupfin operations occur throughout the year, but landings are greatest between September and December. Soupfin sharks are usually caught at <180 m and within 5 miles of shore. In California there are no fishing regulations directed at the soupfin shark other than those imposed on all set nets. Soupfin sharks are also taken in small numbers by related fisheries such as those for halibut, sea bass and angel shark. Current landings for California indicate increased fishing pressure in response to the overall increased demand for shark meat. In Oregon, vessels landed 9,100 pounds in 1985. Most of this occurred in the winter months and most (62 percent) was landed in Astoria. The fishery is managed by the Pacific Marine Fishery Council (PMFC). There are no data at this time to indicate current fishing pressure has affected the local soupfin shark populations.

Blue Shark Fishery

The blue shark, *Prionace glauca*, is not a current target species of any west coast fishery. However, it is taken in large numbers by the California drift gill-net fishery for thresher shark and swordfish. The blue shark is common through-

out all tropical and temperate waters both offshore and inshore. It may be the most common pelagic shark in the world and is common off both U.S. coasts. Blue sharks are highly migratory and individuals tagged off the U.S. east coast have made trans-Atlantic crossings (Casey, et al., 1982). Blue sharks are also known to make extensive, sexually segregated migrations, although local collections indicate large individuals of either sex are uncommon off California. Juveniles abound in southern California coastal waters in the spring and summer months. In the spring, individuals tagged in the waters off Catalina Island exhibit a movement pattern toward the island at dusk and return to the deeper waters in the predawn hours. This pattern is not seen in the summer and fall months (Sciarrotta and Nelson, 1977).

The blue shark is one of the most prolific of pelagic sharks and has a viviparous mode of reproduction. Gestation lasts 9-12 months and litter size varies between 25 and 50 pups (up to 135 have been reported). A von Bertalanffy growth curve based on silver nitrate aging techniques for 130 blue sharks indicates females mature at 5-6 years of age (220 cm) and males at 4-5 years (Cailliet and Bedford, 1983). There are no estimates of mortality.

Preliminary estimates indicate that about 15,000-20,000 (300 metric tons) blue sharks are taken incidentally in other fisheries each year. Gillnet caught blue sharks are unmarketable because the urea in the muscle tissue rapidly breaks down into ammonia soon after death and tainting the meat. A small, one-vessel, experimental longline fishery developed off southern California from 1980 to 1982. This vessel resolved most of the processing problems and produced a good quality product. The warm water conditions of 1982 and 1983 displaced the blue shark population out of the Southern California Bight and interrupted this trial fishery. The blue sharks returned to southern California in the fall of 1983, although the participants in the experimental fishery have not renewed their efforts.

The impact of the drift gillnet operations on the blue shark population has been severe at times, although currently there is no west coast fishery directing effort at the blue shark. Determining incidental fishing mortality from both drift and setnet fisheries is very difficult because the incidental catch of blue shark is dumped at sea. Current catch estimates are lower than in the past because fishermen are using larger mesh nets that catch fewer small sharks and because they tend to avoid areas with a high concentration of blue sharks. These facts along with the fish's relatively high fecundity suggest that the continuing incidental catch has not resulted in a reduction in the local blue shark population.

Spiny Dogfish Fishery

The spiny dogfish, *Squalus acanthias*, is one of the most abundant sharks in cool temperate waters throughout the world's oceans. This small bottom dweller is a very important commercial species and is fished wherever it occurs. In the northeast Pacific the spiny dogfish is common in both inshore and offshore areas of the continental and insular shelf and is commercially abundant off British Columbia and Washington.

The spiny dogfish is a slow and moderately inactive swimmer. At times, large, sexually segregated schools are formed. They are opportunistic feeders on small bottom and epibenthic fish and some pelagic fish such as herring. The composition of prey species varies considerably depending on location, time, and depth. Occasionally large, mixed feeding aggregations of both sexes and all sizes will form. These schools have caused severe losses to fishermen as a result of damaged fishing gear and lost fishing time and catch. The preferred water temperature is 7°-15°C and these sharks will make vertical depth migrations to remain in their comfort zone. Tagging studies conducted in British Columbia and Washington indicate that spiny dogfish are indigenous to the inland waters of Puget Sound, Strait of Georgia, and Hecate Sound, and that there is considerable movement across the U.S.-Canadian border in both directions. These results also showed that less than 2 percent of those tagged in these inland waters were recovered in the open sea. Although some individuals have made extensive movements, both to the south and to the west (2,320 and 7,890 km, respectively), the fishable stocks appear to move only with the seasonal changes in water temperature (Ketchen, 1986).

Reproduction in the spiny dogfish is extremely slow because of the 2-year breeding cycle of the females. They are ovoviviparous and breeding occurs in the fall and early winter months. Litter size is from 1 to 20, but averages only 6-8 fully formed pups after a gestation period of 18-24 months. Growth is exceptionally slow with maturity averaging 14 years for males and 24 years for females. Females mature between 70 and 100 cm and live at least 30-50 years, with some estimates approaching 100 years. Males mature at 59-72 cm and reach a maximum size of 83-100 cm.

The fishery for Pacific dogfish has gone through several stages of growth and decline since before World War II. Traditional use has been for various food products, for export to European and Oriental markets, for reduction, and as fertilizer in the domestic market. Use of the spiny dogfish for food in the U.S. began about 1975. Primary use was for fresh, smoked, and processed meat. Continued growth of this fishery was encouraged by a strong European import market that was suffering from decreased production in the northeast Atlantic. Combined catches of spiny dogfish exceeded 2,600 metric tons in 1976, peaked at 4,681 metric tons in 1979, and has declined in recent years to about 2,600 metric tons (Table 3). U.S. fishing boats operated in Puget Sound where 99 percent of the west coast production was taken, with only incidental landings reported for Oregon and California.

The British Columbia catch followed the same pattern of expansion. Canadian vessels operate primarily in the south coast areas, which accounts for over 90 percent of their catch. Substantial amounts are also taken in Hecate Strait, although production in more distant and coastal fishing areas is limited by the lack of processing plants and the need for immediate processing of the catch. Total catch from these areas also peaked in 1979 with 4,757 metric tons landed

(Table 3), but then declined to an average of 3,000 metric tons between 1982 and 1985.

Although these catch figures seem to indicate a stable fishery, there are some warning signs of overfishing. Several important fishing areas such as Puget Sound and the southern parts of the Strait of Georgia show a decrease in abundance. Depending on the type of fishery, estimates of CPUE give a mixed look at abundance. Canada's sctline fishery shows no increased effort in the Strait of Georgia between 1979 and 1982. On the other hand, CPUE for the trawl fishery in the same area fell steadily from 0.631 to 0.160 metric tons/haul between 1977 and 1982 (Ketchen, 1986). At this time there is no clear indication of the continued stability of this fishery. The economics of this fishery require a high catch per unit of effort because of the low commercial value, the need for close proximity to a processing plant, and a fluctuating market demand.

Estimates of stock size in the northeast Pacific varied between 300,000 and 500,000 metric tons before the great liver fishery during the 1940's. Over 250,000 metric tons of spiny dogfish were caught during this period. Current estimates of maximum sustained yield (MSY) range in the neighborhood of 8,000 to 10,000 metric tons.

Management of the spiny dogfish fishery is under the PMFC groundfish plan.

Table 3.—Annual catch of spiny dogfish in the northeastern Pacific in metric tons, round weight[1].

Year	British Columbia	Wash.	Oregon	Calif.	Total
1970	137	61	8		206
1971	128	12	2		142
1972	116	20	tr		136
1973	5,056	6	tr		5,062
1974	1,070	749	11	tr	1,830
1975	713	508	10	tr	1,231
1976	242	2,635	6	10	2,893
1977	1,730	2,462	122	174	4,488
1978	3,126	2,759	59	200	6,144
1979	4,757	4,284	344	53	9,438
1980	4,544	3,232	135	7	7,918
1981	1,782	2,185		7	3,974
1982	3,914	2,032		3	5,949
1983	3,051	2,423		25	5,499
1984	2,441	3,461		8	5,910
1985	2,680	1,287	tr	tr	3,967

[1]Sources: California Department of Fish and Game, Marine Statistics (1970-84); Washington Department of Fisheries, Statistical Reports (1976-84); Ketchen, 1986.

The MSY and available biological catch (ABC) for Washington have been proposed at 2,900 metric tons (Pedersen and DiDonato, 1982) and the MSY for British Columbia was set at 8,000-10,000 metric tons (Ketchen, 1986). The west coast stock appears healthy, even though there are some warning signs of overexploitation. There is an urgent need for a management policy between the United States and Canada to ensure a stable fishery for the spiny dogfish in the inland areas.

Shark Fisheries in Mexico

Shark fishing in Mexico is poorly documented. Artisanal fisheries and cooperative fishing camps catch various species of sharks, skates, and rays for subsistence uses, as fresh fish for local markets, and as curios. There are also up to two Mexican longline vessels that target exclusively for thresher and mako sharks. Records are essentially nonexistent for most of these catches. The greatest amount of sharks taken off Baja California is by long-line joint venture operations with Japan.

Japanese long-line vessels have been fishing off the coast of Baja California since the early 1960's. The principal targets of these operations are striped marlin, *Tetrapturus audax*; sailfish, *Istiophorus platypterus*; swordfish, and tunas. Sharks are taken incidentally and delivered to markets in Mexico; the more expensive fish are delivered to Japan.

As many as 18 vessels operated from these ports between 1980 and 1984. These cooperative fishing operations were temporarily suspended between 1984 and early 1986. Currently, Japan and Korea each have six longline vessels licensed to operate out of Ensenada, B.C., Mex. There are an additional three active longliners operating from Mazatlan, and one from Manzanillo.

Catches of all shark species are combined into one shipboard reporting category, and the catch of individual species is not recoverable. Although the species composition is unknown, both common and bigeye threshers and bonito sharks reportedly make up the major portion of the shark catch. These records indicate combined shark catches represent up to

Table 4.—Landings and CPUE of Mexican-Japanese joint venture fisheries operating in Baja California. The number and weight of sharks listed here should be considered a minimum due to reporting irregularities.

Year	No. of sharks	Metric tons	Year	No. of sharks	Metric tons
1980[1]	290	19	1983	17,377	331
1981		181	1984[1]	1,394	33
1982	8,949	191			

[1]Incomplete data.

33 percent by weight (42 percent by number) of the total longline catch (Table 4). The reported shark catch for these vessels averaged 234 metric tons between 1981 and 1983.

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Relative Abundance and Fishery Potential of Pelagic Sharks Along Florida's East Coast

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Introduction

Relative abundance and fishery potential of pelagic sharks were investigated by sampling the shark by-catch aboard commercial swordfish, *Xiphias gladius*, longline vessels along Florida's east coast. The longline fishery for swordfish in this area, which began in 1975, underwent a very rapid fleet expansion, and by 1980 there were an estimated 200 vessels engaged in the fishery (Berkeley et al., 1981). Landings increased steadily to 3.2 million pounds in 1980, declining slightly to about 3.0 million pounds in the early 1980's[1]. Fleet size declined to between 50 and 100 boats, although the fishing power of these vessels far exceeded that of the initial fleet (SAFMC, 1985a).

ABSTRACT—Catch rates, relative abundance, and some biological information on various shark species were documented during a 2-year study of the shark by-catch of the swordfish, Xiphias gladius, *fishery off Florida's east coast. A total of 613 sharks composed of 13 species were recorded in the study area from September 1981 to September 1983. Seasonal trends in the abundance of all sharks combined were consistent between years with high abundance from September to November and a secondary peak in February and March. Likewise, in both years, night,* Carcharhinus signatus; *silky,* C. falciformis; *and scalloped hammerhead,* Sphyrna lewini, *sharks dominated the catch, comprising 86 percent of the total shark catch.*

The annual mean shark CPUE was 4.16 sharks per 100 hooks set, compared with an annual mean swordfish CPUE of 3.67. It was estimated that, annually, at least 4.8 million pounds of sharks were caught along the east coast of Florida incidental to swordfishing during the years of the study. The average annual reported shark landings during the same period was only 3.3 percent of this estimated catch. Our results indicated that, for most species, females predominated in the catch and that 89 percent of these were below their reported size at maturity. This, combined with the observed 66 percent mortality rate of hooked sharks, suggests that the development of a fishery, directed or otherwise, should proceed with caution.

Pelagic sharks constitute, by far, the largest component of the incidental catch in this fishery, generally exceeding the swordfish catch (Anderson, 1985). Until 1981, there was little market for sharks in Florida and, with the exception of the shortfin mako, *Isurus oxyrhincus*, nearly all sharks were discarded at sea. In 1981, demand for sharks began increasing and, while the ex-vessel price was still too low to support a directed fishery ($0.35 - $0.50/pound dressed weight), it was sufficient to encourage swordfish fishermen to land their by-catch. Since then, demand has fluctuated considerably, but the ex-vessel price has remained almost constant. In contrast, during the same period the price of swordfish increased from an average of $1.75/pound (Cato and Lawlor, 1981) to perhaps $3.00/pound. This decline in relative value, combined with the difficulty of landing sharks and the careful processing and handling required to maintain the necessary quality (Otwell, 1984) have discouraged many fisherman from retaining them. Nonetheless, since the feasibility of harvesting these pelagic sharks is largely dependent on the profitability of the swordfish fishery, the low ex-vessel price will not necessarily preclude their exploitation.

While pelagic sharks may be underutilized, they are not necessarily underexploited. In an analysis of various fisheries that directly or indirectly catch pelagic sharks, Anderson (1985) suggests that sharks in both the Atlantic and the Gulf of Mexico may already be overexploited. Whether or not this is so, the slow growth rates and low reproductive potential of sharks greatly increase the possibility of overfishing (Holden, 1974), making careful monitoring of the fishery and the resource essential if such problems are to be avoided.

Little quantitative information is available on the distribution, abundance, or biology of the various species of pelagic sharks found off the southeast U.S. coast. Casey and Hoey (1985) present the species composition recorded in the U.S. recreational fishery in 1978 for the Atlantic south of Virginia. They also summarize the species composition of sharks recorded during an unspecified period on

[1]Unpublished swordfish landings data, corrected and revised at the NMFS Southeast Fisheries Center Swordfish Stock Assessment Workshop, Miami, Fla., 16-26 April 1986.

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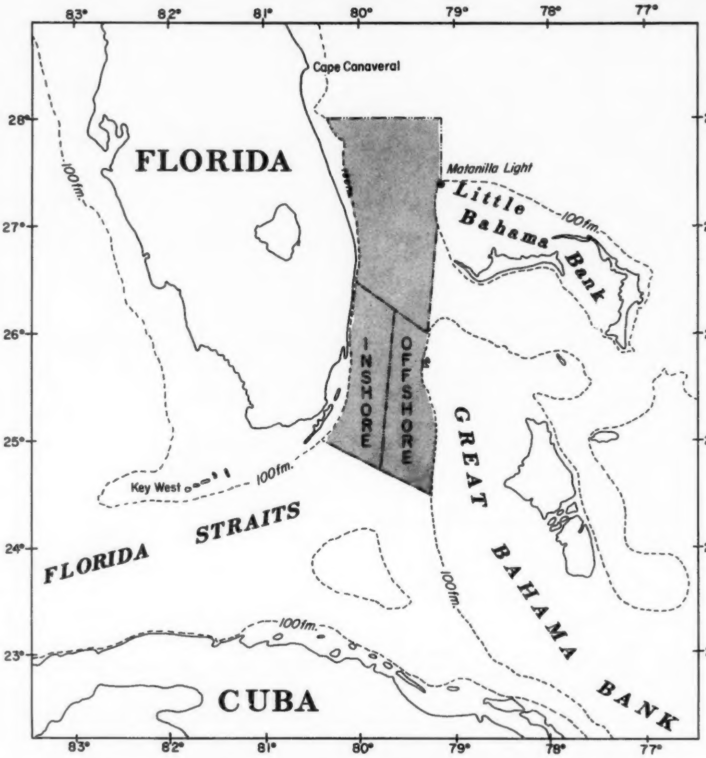


Figure 1.—Location of sampling area (shaded), including designated "inshore" and "offshore" areas.

310 longline sets in the same area. Hammerhead, *Sphyrna* spp. was the most commonly captured shark in both fisheries, followed, in the longline fishery, by blue, *Prionace glauca*; sandbar, *Carcharhinus plumbeus*; dusky, *C. obscurus*; blacktip, *C. limbatus*; and tiger, *Galeocerdo cuvieri*. Burgess (1984) documented species frequently caught in the inshore and offshore areas off Florida. Nurse, *Ginglymostoma cirratum*; bull, *C. leucas*, sandbar, and hammerhead sharks were common inshore species, while bigeye thresher, *Alopias superciliosus*; mako, *Isurus* spp.; bignose, *C. altimus*; silky, *C. falciformis*; night, *C. signatus*; and oceanic whitetip, *C. longimanus*, sharks were common offshore. Scalloped hammerhead, *S. lewini*; dusky, and tiger sharks were frequently caught in both areas. Spatio-temporal distribution patterns are more complex than this because most sharks make seasonal migrations, both north-south and inshore-offshore, largely related to temperature and reproductive cycles (Ronsivalli, 1978; Burgess, 1984). In addition, such behavior is modified by the age structure of the population. Younger (smaller) sharks of some species exhibit behavioral separation in space and time from older (larger) members of the population (Lineaweaver and Backus, 1970; Casey, 1976). The same has been noted between males and females of some species (Ronsivalli, 1978; MAFMC, 1980). Due to these behavioral characteristics, the wide and incompletely understood distribution of many species, and the limited amount of quantititative sampling that has been conducted, there is a paucity of data critical for assessing the state of shark populations.

In this paper, which is based on the results of a 2-year study, we present baseline information on catch rates and relative abundance, and some notes on the biology of common species within the context of examining the fishery potential of the shark resource along Florida's east coast.

Methods

Between September 1981 and September 1983, a total of 111 longline sets were made off the east coast of Florida between lat. 24°30′ and 28°00′ N (Fig. 1). Standard Florida-style swordfish longline gear and methods were used, as described in Berkeley et al. (1981). Most sets were made from the *Doc's Out III*, a small commercial swordfish longliner, which fished 9 miles of mainline and 90-120 hooks per set. Other vessels in the fleet set up to 25 miles of mainline and over 300 hooks. Sets were begun around sunset and the gear was allowed to soak until shortly before sunrise, when haulback began. Squid was generally used as bait, although white mullet, *Mugil curema*, was used occasionally. A chemical light stick (Cyalume[2]) was attached to the leader 3-5 feet above each hook. Leaders were single strand, 250-pound test monofilament, 80-120 feet long. Effort was expressed as total number of hooks set. Number of hooks bitten off, species composition of the catch, number of swordfish, number of sharks and their location on the line, the condition of the fish (dead or alive), and the geographical coordinates of the longline were also recorded at sea.

Generally, all sharks were retained except hammerheads, whose meat had no market value and which were cut free if alive. All sharks retained were kept whole until returning to port, where they were identified, weighed to the nearest pound, measured (snout-fork length in cm), and sexed. Stomach contents were recorded and preserved, females were examined for reproductive activity (presence of embryos), and vertebrae were taken for future ageing studies. Live hammerheads were identified, sexed, their lengths estimated, and cut free. Aboard vessels other than the *Doc's Out*

[2]Mention of trade names or commerical firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

Table 1.—Results of t-tests comparing mean CPUE of swordfish and sharks between inshore and offshore areas from February through April 1982.

Area	Number of sets	Number of hooks[1]	Mean CPUE for swordfish[2]	Mean CPUE for sharks[2]
Inshore	8	990	2.61	6.31
Offshore	6	681	2.46	3.77
			$t_s = 0.14$	$t_s = 0.93$
			df = 12	df = 12
			$P > 0.40$	$0.25 > P > 0.10$

[1]Only those hooks on monofilament leaders
[2]Standardized catches on monofilament leaders. (Arcsine transformation did not change results).

Table 2.—Results of t-tests comparing mean CPUE of swordfish and sharks between stainless steel and monofilament leaders used in sets from September 1981 to March 1982 (tests performed on arcsine-transformed data).

Type of leader	Number of leaders in 13 sets	Mean CPUE for swordfish	Mean CPUE for sharks
Steel	338	2.40	4.66
Monofilament	1,266[1]	5.55	5.44
		$t_s = 2.50$	$t_s = 0.99$
		df = 24	df = 24
		$P < 0.01$	$0.25 > P > 0.10$

[1]Mean proportion of steel leaders in 13 sets = 21.1 percent.

Table 3.—Number of sets, hooks, hooks lost, and mean CPUE of swordfish and sharks by month, September 1981 to September 1983.

Year and month	No. of sets	No. of hooks	Mean CPUE: Swordfish	Mean CPUE: Sharks	Mean no. of hooks lost/100 hooks set
Year 1					
Sept. '81	3	365	7.94	5.66	3.18
Oct.	7	836	5.48	7.80	7.44
Nov.	4	404	5.36	2.63	5.04
Dec.	6	709	2.38	3.83	4.58
Jan. '82	5	593	2.63	3.32	4.96
Feb.	3	387	1.04	6.96	7.75
Mar.	4	512	2.16	5.38	4.43
Apr.	7	887	3.21	4.37	6.05
May	5	625	3.84	3.83	8.61
June	6	700	2.53	2.37	4.36
July, Aug.	Data unavailable				
Subtotal	50	6,018	3.66	4.70	5.75
Year 2					
Sept.	7	758	12.38	6.94	12.00
Oct.	8	1,321	3.28	5.61	3.98
Nov.	4	786	6.41	5.93	7.11
Dec.	3	490	4.64	2.02	2.03
Jan. '83	3	547	1.76	2.56	2.02
Feb.	5	849	2.73	3.55	3.10
Mar.	3	443	0.71	3.84	1.78
Apr.	14	2,068	3.10	2.74	3.92
May	6	799	0.96	1.36	5.80
June	2	202	0.86	2.28	1.14
July	Data unavailable				
Subtotal	55	8,263	3.54	3.52	4.19
Aug. '83	2	196	4.04	6.21	2.95
Sept.	4	404	5.59	4.72	5.77
Grand total	111	14,881	3.67	4.16	4.93

III, only species, sex, and estimated length could be recorded as most sharks were cut off at the boat.

To standardize effort, catches were expressed as number of sharks per 100 hooks (CPUE). Most set records included information on whole weights and, when possible, dressed weight (headed, eviscerated, and fins removed) of individual specimens. If not, weights were approximated using available length-weight conversions (MAFMC, 1980) or using the monthly mean weight of the particular species if lengths had not been recorded.

During the initial phase of the study, sets were made in both "inshore" and "offshore" areas. The inshore area is defined as the area from the 100-fathom contour off the Florida mainland out 15 miles, while the offshore area extends eastward from there to approximately the 200-fathom contour on the eastern side of the Florida Straits (Fig. 1). Catch rates between these two areas were compared.

The fishery presently uses monofilament leaders, which allow most large sharks to escape by biting through them. We hypothesized that those sharks that escaped would be larger and of different species composition than those retained. In an attempt to test this hypothesis and determine if we could retain a higher percentage of sharks, 20-25 percent of the leaders were replaced with stainless steel, multi-stranded cable (500-pound test). Statistical comparisons were performed on catch rates between the two leader types.

Monofilament leaders are used in the longline fishery because they increase the swordfish catch (Berkeley et al., 1981). However, hooks are often missing when the longline is retrieved. Although any large fish may break a worn leader occasionally, most missing hooks are believed to have been bitten off. Based on the composition of species retained by the gear, there are few fish other than sharks which would appear capable of routinely severing 250-pound test monofilament. Thus, we recorded the number of missing hooks because we believe that this reflects primarily escaped sharks.

Results

Catch Rates

Both inshore and offshore areas were fished from February through April 1982. The mean CPUE of sharks was 2.4 times higher in the inshore area, but the difference was not statistically significant (t-test, $0.25 > P > 0.10$) (Table 1). Swordfish catch rates were almost identical between the two areas (t-test, $P > 0.40$). In both inshore and offshore sets, more sharks than swordfish were caught.

Stainless steel leaders were not effective in increasing the shark catch (Table 2). Despite the fact that many sharks escaped by biting through the monofilament leaders, as suggested by the number of missing hooks (Table 3), the steel leaders caught fewer sharks, although the difference was not significant ($0.25 > P > 0.10$) (Table 2). In addition, there was no apparent difference in the size or species composition of sharks caught on steel leaders compared with monofilament. However, the catch rate for swordfish on steel leaders was significantly less than for monofilament ($P < 0.01$). Steel leaders were only 43 percent as effective in catching swordfish and 86 percent as effective in catching sharks as were monofilament leaders. Because of this, steel leaders were no longer used after March 1982.

A total of 613 sharks and 523 swordfish weighing 70,677 and 35,547 pounds, respectively, were recorded in 111 longline sets fished off the southeast Florida coast during the study. Complete hook information was recorded for 102 sets. Total number of hooks in the 102 sets was 13,799. The monthly mean shark CPUE ranged from 1.36 (May 1983) to 7.80 (October 1981), compared

Table 4.—Number of individuals of each shark species recorded in each month from September 1981 to September 1983.

	Year 1												Year 2														
	1981				1982												1983										Percent of
Species	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	Species total	grand total
Bigeye thresher	1	2				1								1			1	1		1		2				10	1.6
Bignose									4	2						2	5	2		1					1	17	2.8
Silky	7	10	8	12	12	4	4	8	3	4			22	11	5	2	1	10	7	15	4			9	9	167	27.2
Bull																			1	1						2	0.3
Oceanic whitetip		1		2			1			2				3			1	1		2						13	2.1
Dusky	1	3			1					1										1						7	1.1
Sandbar									1																	1	0.2
Night	10	40		5	4	7	3	21	6				17	23	2			3		3	6	3		2	5	160	26.1
Tiger						1	1							1	3			1			1				1	9	1.5
Longfin mako														1		1										2	0.3
Blue			3	3																3						9	1.5
Scal. hammerhead	2	5		2	1	10	18	7	9	16			11	16	36	5	6	11	5	34		3		1	1	199	32.5
Great hammerhead		2			1				1																	4	0.7
Unident. sharks		2			1	3	1			1					1			3		1						13	2.1
Monthly and grand total	21	65	11	24	20	26	28	36	24	26			50	56	47	10	14	32	13	62	11	8		12	17	613	100.0

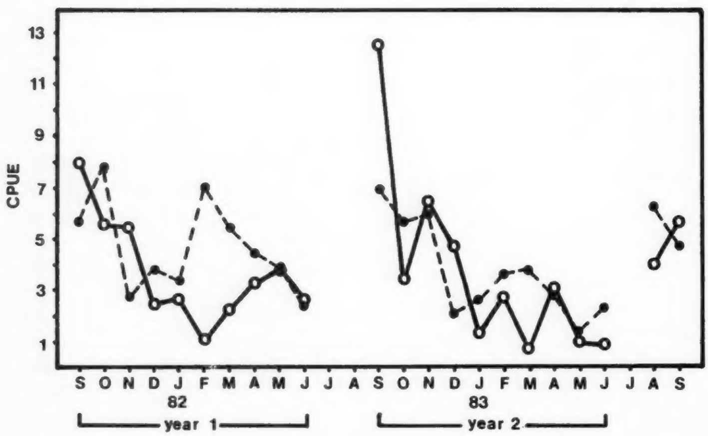


Figure 2.—Monthly mean number of sharks (dots) and swordfish (circles) caught per 100 hooks from September 1981 to September 1983.

with a range for swordfish of 0.86 (June 1983) to 12.38 (September 1982) (Table 3). Sharks constituted 53 percent by number of the recorded total catch (excluding other incidental teleosts) and had an overall mean CPUE of 4.16. Sixty-six percent (n=592) of the sharks brought alongside were dead.

Sharks were most abundant during late summer and fall (September-November), with a secondary peak during late winter and early spring (February and March) (Fig. 2). Although mean CPUE's were not significantly different among months (ANOVA, $P > 0.50$), the same patterns were seen in both years. Data for July and August 1982 and July 1983 were unavailable and therefore do not necessarily represent low abundances or low effort. Year 1 (September 1981 through June 1982) showed high CPUE's in September and October 1981 and February and March 1982, while year 2 (September 1982 through June 1983) showed high CPUE's in September to November 1982 and February and March 1983. Following the same trend, CPUE increased in August and September 1983. Although mean CPUE for the first year (4.70) was higher than for the second year (3.52), the differences were not significant (t-test, $0.20 > P > 0.10$). Likewise, CPUE for swordfish was not statistically different between years ($P > 0.40$), although a slight decrease was seen, from 3.66 in year 1 to 3.54 in year 2. Seasonal trends in swordfish CPUE were also consistent for both years with highest values (in numbers) in the late summer and fall months. While catches of both sharks and swordfish declined the second year, their relative proportions remained fairly constant. Shark catch rates represented 56 and 50 percent of the overall yearly mean total catch rate in the first and second years, respectively (Table 3).

Species Composition and Relative Abundance

Of the 13 species of shark recorded during the study, night, silky, and scalloped hammerhead sharks collectively represented 86 percent of the total shark catch in numbers (Table 4). Although the catch of both scalloped hammerhead and silky sharks exceeded the catch of night sharks (Table 4), night sharks had the highest overall mean CPUE, 1.21 (Table 5). This species represented >50 percent of the monthly CPUE in October and April of the first year and in May of the

Table 5.—Monthly mean CPUE for the six most abundant species of shark and their percent of the monthly CPUE (in parantheses) for all sharks from September 1981 to September 1983.

	1981				1982						
Species	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Year 1
Bigeye thresher	0.25	0.23				0.26					0.07
	(4.4)	(3.0)				(3.7)					(1.5)
Bignose									0.64	0.61	0.11
									(16.7)	(25.7)	(2.3)
Silky	1.86	1.19	1.92	1.03	1.96	1.04	0.76	1.02	0.48	0.33	1.16
	(32.9)	(15.3)	(73.0)	(26.9)	(59.0)	(14.9)	(14.1)	(23.3)	(12.5)	(13.9)	(24.7)
Oceanic whitetip		0.13		0.30			0.20			0.61	0.11
		(1.7)		(7.8)			(3.7)			(25.7)	(2.3)
Night	2.77	4.83		0.87	0.68	1.80	0.58	2.33	0.96		1.69
	(48.9)	(61.9)		(22.7)	(20.5)	(25.9)	(10.8)	(53.3)	(25.1)		(36.0)
Scal. hammerhead	0.49	0.59		0.35	0.17	2.83	3.66	0.69	1.44	0.33	0.95
	(8.7)	(7.6)		(9.1)	(5.1)	(40.7)	(68.0)	(15.8)	(37.6)	(13.9)	(20.2)
All sharks combined	5.66	7.80	2.63	3.83	3.32	6.96	5.38	4.37	3.83	2.37	4.70

Table 5.—Continued.

	1982				1983							1983		
Species	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Year 2	Aug.	Sep.	Overall
Bigeye thresher		0.09						0.07		0.57	0.05			0.06
		(1.6)						(2.6)		(25.0)	(1.4)			(1.4)
Bignose				0.43	0.92	0.21		0.04			0.12		0.24	0.11
				(21.3)	(35.9)	(5.9)		(1.5)			(3.4)		(5.1)	(2.6)
Silky	1.50	0.93	0.62	0.39	0.19	1.15	2.25	0.63	0.54		0.80	4.76	2.77	1.12
	(21.6)	(16.6)	(10.5)	(19.3)	(7.4)	(32.4)	(58.6)	(23.0)	(39.7)		(22.7)	(76.6)	(58.7)	(26.9)
Oceanic whitetip		0.26			0.18	0.13		0.12			0.09			0.10
		(4.6)			(7.0)	(3.7)		(4.4)			(2.6)			(2.4)
Night	3.10	2.71	0.25			0.36		0.17	0.73	0.86	0.75	0.96	1.20	1.21
	(44.7)	(48.3)	(4.2)			(10.1)		(6.2)	(53.7)	(37.7)	(21.3)	(15.5)	(25.4)	(29.1)
Scal. hammerhead	2.35	1.44	4.68	1.01	0.99	1.19	0.91	1.49		0.86	1.46	0.48	0.27	1.16
	(33.9)	(25.7)	(78.9)	(50.0)	(38.7)	(33.5)	(23.7)	(54.4)		(37.7)	(41.5)	(7.7)	(5.7)	(27.9)
All sharks comb.	6.94	5.61	5.93	2.02	2.56	3.55	3.84	2.74	1.36	2.28	3.52	6.21	4.72	4.16

second year. Scalloped hammerheads had an overall mean CPUE of 1.16 and were the most abundant species in March of year 1 and in November, December, and April of year 2. Silky sharks had an overall mean CPUE of 1.12 and comprised >50 percent of the monthly CPUE's in November and January of year 1, March of year 2, and again in August and September of the following year.

Annual mean CPUE's for night, silky, and scalloped hammerhead sharks were 36, 25, and 20 percent, respectively, of the annual total mean CPUE during year 1. Similarly, in the second year, annual mean CPUE's were: Scalloped hammerheads, 42 percent; silky sharks, 23 percent; and night sharks, 21 percent of the total mean CPUE.

Biological Information

Only cursory biological data was collected during this study, primarily because of the small number of most species collected.

A total of 203 sharks were examined for stomach contents. Of these, 171 (84 percent) had empty stomachs. Because of this high percentage, meaningful conclusions on feeding habits cannot be made.

The overall sex ratio observed for all species combined was 1.7 females to 1 male (n=573) (Table 6). All dead female sharks were examined for developing embryos or "pups." Of 142 female night sharks examined, only 2 (1.4 percent) were pregnant. Similarly, only 2 of 79 (2.5 pecent) female silky sharks were pregnant. The number of pups was highly variable both among and within species (Table 7).

Table 6.—Sex ratios and percent females of shark species recorded in the Florida Straits from September 1981 to September 1983.

Species	Ratio F:M	Percent female	Sample size
Bigeye thresher	3.9:1	73.0	34
Bignose	1.1:1	53.3	15
Silky	1.5:1	60.3	141
Bull	2.0:1	66.7	3
Oceanic whitetip	6.0:1	85.7	7
Dusky	0.7:1	40.0	5
Sandbar	1.0:0	100.0	1
Night	1.7:1	62.9	240
Tiger	7.0:1	87.5	8
Longfin mako	1.0:0	100.0	1
Blue	3.0:0	100.0	3
Scalloped hammerhead	1.6:1	61.8	110
Great hammerhead	1.0:1	50.0	4
All sharks	1.7:1	63.0	573

Table 7.—Specimen fork length, number of embryos, size range of embryos, and date of capture of specimens with embryos.

Species	FL (cm)	Month and year collected	No. of embryos	Size range of pups (TL in cm)
Night	211	Apr. 1982	20	
Night	215	Apr. 1982	14	
Silky	223	Sept. 1981	10	25.8-29.3
Silky	221	Sept. 1982	3	52.5-61.8
Bigeye thresher[1]	239	Sept. 1981	2	11.1-11.9
S. hammerhead	215	Jan. 1982	22	30.2-36.3

[1]This specimen also contained 28 egg sacs, and both pups still had external gills.

Table 8.—Mean fork length (cm), size range (FL in cm), and mean whole weight (pounds) of 13 species of sharks recorded from September 1981 to September 1983. Sample size is given in parentheses.

Species	Mean FL: Male		Mean FL: Female		Data for combined sexes: Mean FL		Size range	Mean wt.	
Bigeye thresher	195.1	(7)	204.4	(20)	202.0	(27)	78-244	172.0	(3)
Bignose	161.3	(7)	102.9	(8)	127.4	(17)	70-207	117.7	(7)
Silky	113.1	(52)	111.6	(79)	112.9	(151)	58-233	46.0	(85)
Bull			233.7	(3)			198-274		
Oceanic whitetip	129.0	(2)	126.0	(4)	126.3	(7)	99-183	74.0	(3)
Dusky	210.3	(3)	188.0	(1)	200.4	(5)	183-235	188.5	(2)
Sandbar			184.0	(1)	160.5	(2)	137-184	161.0	(1)
Night	146.0	(90)	156.1	(142)	150.4	(298)	68-234	103.9	(69)
Tiger	300.0	(1)	236.8	(6)	225.1	(9)	122-303	688.3	(3)
Longfin mako			229.0	(1)	232.5	(2)	229-236		
Blue			192.3	(3)	178.5	(4)	137-205	120.0	(1)
S. hammerhead	162.1	(47)	161.6	(74)	163.5	(152)	91-244	174.4	(8)
Gr. hammerhead	199.0	(2)	157.0	(2)	178.0	(4)	140-230	265.0	(1)

Length and Weight

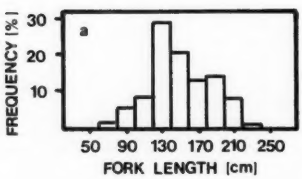
Mean individual whole weight of all sharks combined was 93.0 pounds (n=183). Mean lengths, size range, and mean weights for 13 species of sharks are presented in Table 8. Sufficient data were recorded to calculate length-weight relationshsips for night and silky sharks. Despite the small sample size, the equation for bignose sharks is included because of the high correlation coefficient (r).

night $WT=0.000028 \times FL^{2.9394}$ $n=61$ $r=0.995$

silky $WT=0.000018 \times FL^{3.0327}$ $n=80$ $r=0.980$

bignose $WT=0.000014 \times FL^{3.0738}$ $n=7$ $r=0.997$

where: WT=whole weight (pounds)
FL=fork length (cm)
n=sample size
r=correlation coefficient



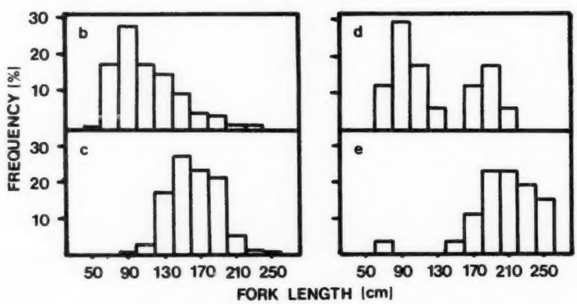


Figure 3.—Length frequency distribution of (a) night (n=312), (b) silky (n=153), (c) scalloped hammerhead (n=154), (d) bignose (n=17), and (e) bigeye thresher (n=26) sharks recorded from September 1981 to September 1983.

Size frequency distributions for combined sexes of night, scalloped hammerhead, silky, bigeye thresher, and bignose sharks are shown in Figure 3a-e.

Fishery Potential

The overall mean CPUE was 4.16 (n=111 sets) sharks per 100 hooks, with a mean individual weight of 93.0 pounds. Based on data derived from commercial swordfish permits for 1983, it was estimated that an annual total of 1,252,450 hooks were set for swordfish off the east coast of Florida (SAFMC, 1985b). If these figures are accurate, then the estimated annual shark by-catch was about 4.8 million pounds. This figure is probably conservative because the estimated number of hooks per year is derived from the assumption that each vessel made only one trip per month (of mean duration, 6.7 days). The average annual reported shark landings for the Florida east coast from September 1981 to September 1983 was 175,752 pounds[3], 90 percent (=158,177 pounds) of which were believed to have come from swordfish longline vessels[4]. Therefore, the annual shark

[3]Statistical Survey Branch. 1985. Florida landings, 1981, 1982, 1983. Southeast Fisheries Center, National Marine Fisheries Service, NOAA, 75 Virginia Beach Drive, Miami, FL 33149.

[4]E. Snell, Southeast Fisheries Center, National Marine Fisheries Service, NOAA, 75 Virginia Beach Drive, Miami, FL 33149. Personal commun.

landings by longline vessels during this period was no more than 3.3 percent of the estimated annual shark by-catch.

Discussion

The restricted extent of the study area, the limited number of sets, and the low catch rates typical of pelagic longlining all combine to limit statistical precision and restict our ability to confidently generalize from the results of this study. However, assuming our results are reasonably representative, the shark by-catch from this limited area was at least 4.8 million pounds. Because of the low value of sharks, fishermen are generally unwilling to go through the handling procedures needed to ensure a marketable product, and most of the catch is discarded at sea. Even though most sharks are released, we found that 66 percent of the sharks brought alongside were dead. The effect of this source of mortality on natural populations is not known, but may be significant. Using previously presented estimates of CPUE and fishing effort, the mortality due to longline fishing off the east coast of Florida is estimated to have been at least 52,102 sharks per year.

The present low value of sharks and the high cost of fishing pelagic longline gear precludes the development of a year-round directed shark fishery. However, catch rates in certain times and areas may be sufficiently high for a seasonal fishery to be economically feasible even at the present market value. In both years of the study, shark abundance was highest from September to November, and increased again in February and March. The catch rate in the inshore area was 1.7 times higher than in the offshore area during late winter and early spring. While we suspect the difference may be real, it was not statistically different, probably because of the small sample size and inherent variability in catch rate.

Night, scalloped hammerhead, and silky sharks dominated the catch in both years, comprising 86 percent of the total shark catch. Exploratory longline fishing cruises in the Gulf of Mexico, Caribbean Sea, and the southestern North Atlantic during the 1950's and 1960's found silky, oceanic whitetip, and dusky sharks the three most abundant species, comprising 75 percent of all shark catches (Bullis, 1976). In a series of 310 swordfish longline sets in the Atlantic south of Virginia, summarized by Casey and Hoey (1985), the three most abundant shark species were hammerhead, blue, and sandbar. The catch was not dominated by these species, though, which together comprised only 48 percent of the total shark catch. Suprisingly, night and silky, two of the three most abundant species in our study, were not listed as having been caught, although they may have been included in the category "other." It is unlikely that the difference in species composition observed in the present study represents a change in species distribution or abundance. Rather, it probably reflects differences in fishing gear and methods and the more restricted sampling in our study, an area where night, silky and hammerhead sharks are particularly abundant (Guitart-Manday, 1975; MAFMC, 1980; Burgess, 1984).

Relative abundance of these species changed somewhat from the first year to the second (Table 5), but no consistent seasonal trend in species dominance was apparent. Species composition was likewise slightly different between the two years. Great hammerhead, *S. mokarran*, and sandbar sharks were only recorded in the first year, while bull and longfin mako, *I. paucus*, sharks were only recorded in the second year. This is almost certainly a reflection of the relative rarity of these species in this pelagic habitat, rather than a change in their availability or abundance.

The overall shark by-catch was 117 percent of the swordfish catch. Anderson (1985) found a 296 percent shark by-catch based on 28 swordfish longline sets between Cape Hatteras and the Florida Keys. Since this estimate was derived from sets made in years prior to 1980, it is possible that a real change in relative abundance occurred during this time. However, it is more likely that the difference is a result of improvements in gear and fishing methods that have differentially increased the effectiveness of longlines on their target species, swordfish.

The mean weight of all sharks combined in the present study was 93.0 pounds (42 kg). Using a mean weight of each species weighted by a considerably different species composition than the one we observed, Anderson (1985), no doubt coincidentally, derived an identical overall mean shark weight of 42 kg.

Although our study was confined to the east coast of Florida, the species involved are widely distributed and are impacted by other fisheries in other parts of their range. Commercial longline vessels fishing for swordfish and tunas throughout the Atlantic take a significant by-catch of sharks. A directed U.S. recreational shark fishery and other by-catch fisheries represent additonal sources of fishing mortality. Because sharks are particularly vulnerable to overfishing (Holden, 1974), if a significant proportion of the stock of the species involved is impacted by these fisheries, then even in the absence of a directed fishery, there may be cause for concern. Although there is insufficient information available on stock size or structure of any species of shark to evaluate the impact of these sources of mortality, Anderson (1985) presents evidence that sharks in the Atlantic may already be over-exploited.

Of additional concern is the preponderance of females in the catch of virtually all species (Table 6). Further, it appears that a large proportion of the females of the various shark species in the catch are immature (Table 9). For the ten species for which size at maturity was

Table 9.—Size at maturity[1] and percent of females presumed to be immature (i.e., below reported size at maturity) for sharks collected from September 1981 to September 1983.

Species	Sample size	Size at maturity (FL in cm)	Percent of females immature
Bigeye thresher	20	239[2]	80
Silky	79	180	91
Bull	3	210	33
Oceanic whitetip	4	180	100
Dusky	1	200[3]	100
Sandbar	1	180	0
Night	151	211[2]	89
Tiger	6	340[3]	83
Blue	3	180	0
S. hammerhead	75	215[2]	95
Total	343		88.6

[1]Unless otherwise specified, sizes at maturity were taken from MAFMC (1980); information for other species not available.
[2]Fork lengths of mature females recorded in this study.
[3]From Gubanov (1978).

available, about 89 percent of the females recorded in this study were below that size. These results suggest that pelagic sharks along the east coast of Florida may be especially vulnerable to overfishing.

Our results, which show a 25 percent decrease in shark CPUE from year 1 (4.70) to year 2 (3.52) (Table 3), combined with the high mortality of hooked sharks and the preponderance of immature females in the by-catch, suggest that the development of a shark fishery, directed or otherwise, should proceed with caution.

Acknowledgments

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Estimate of the Catch of Red Snapper, *Lutjanus campechanus*, by Shrimp Trawlers in the U.S. Gulf of Mexico

ELMER J. GUTHERZ and GILMORE J. PELLEGRIN

Introduction

Red snappers, *Lutjanus campechanus*, have been the object of intense commercial fishing in the Gulf of Mexico. Average annual landings of red snapper from 1965 to 1982 were: 1965-71, about 11 million pounds; 1972-76, 800,000 pounds; and 1978-82, 549,000 pounds. Recreational catches of snappers caught in the Gulf of Mexico were substantially higher than commercial catches. Recreational snapper catches for 1965 and 1970 were 44 and 15 million pounds, respectively (Nakamura, 1976). Marine recreational fishing surveys indicated that about 75 percent of the reported snapper catch was red snapper (Thompson, 1979). The recreational take of snappers is substantial and should be considered in management decisions (Prochaska and Cato, 1975; Nakamura, 1976).

Extensive efforts have been expended documenting both the fishery (Ginsburg, 1930; Captiva and Rivers, 1960; Carpenter, 1965; Allen and Tashiro, 1976) and the taxonomy (Rivas, 1966, 1970; and Anderson, 1967) of snappers. Fewer reports, however, address the life history of these species (Camber, 1955; Moseley, 1966; Bradley and Bryan, 1976; Futch and Bruger, 1976).

Commercial and recreational fishermen repeatedly have had to increase travel distances to locate profitable fishing grounds because of declining catch rates in traditional areas. Commercial fishermen who used to fish profitably in the U.S. Gulf of Mexico now often travel to the Caribbean Sea for good catches. Increases in party boat size and in the number of large private craft have made offshore reefs, rock piles, and oil platforms, once exploited only by commercial interests, available to recreational anglers.

The commercial shrimp fishery has been suggested as a possible cause of declining U.S. Gulf snapper landings (Bradley and Bryan, 1976). This suggestion was addressed in the Gulf of Mexico Fishery Management Council Fishery Management Plan for reef fish resources (GMFMC, 1980) but remained unresolved because existing analyses were insufficient.

This paper, utilizing available commercial by-catch and resource assessment data provides a more precise estimate of the catch of juvenile red snapper by shrimp trawlers than that reported in the GMFMC (1980) Reef fish Management Plan. In addition, the information provided may be useful for estimating the timing of first exploitation of red snapper by the shrimp fishery.

Materials and Methods

Fishing catch data were obtained from two sources: The commercial shrimp fleet and National Marine Fisheries Service (NMFS) resource assessment cruises. Commercial data were obtained from three Gulf of Mexico shrimp fleet monitoring projects of the NMFS Mississippi Laboratories: 1) the Domestic Observer Program; 2) the Sea Turtle Incidental Catch Project; and 3) the Shrimp Fleet By-Catch Study. In all projects, data were collected from commercial vessels using standard shrimp trawls aboard trawlers operating in the northern Gulf.

Resource assessment data were collected on NMFS bottomfish surveys including several Southeast Area Monitoring and Assessment Program (SEAMAP) cruises. Northern and western Gulf (Fig. 1, statistical subareas 10-21) bottomfish cruises employed a stratified random sample design with samples generally taken using a standard SEAMAP 42-foot shrimp trawl with 8-foot × 40-inch doors. Infrequently, 55-foot and 70-foot nets with 10-foot × 44-inch doors also were used.

Samples were processed similarly for both data sources. At least 10 percent of the total live weight of the catch was sampled; it was then sorted and weighed by species, individuals of each species counted, and the data recorded on uniform data sheets for subsequent keypunching and computer processing. Collected data also included date, position, depth of capture, trawl headrope length, minutes fished, and time of day.

Data analysis was restricted to juvenile red snapper, as defined by Futch and Bruger (1976). These were specimens less than 1 year old (weighing less than 114 g or 1/4 pound and measuring less than 200 mm FL) and sexually immature.

Fish were not weighed individually. A mean weight per individual was computed for each sampling site by dividing total species weight by the number of specimens. This technique may occasionally be misrepresentative because juveniles caught with many large fish may not have been counted, and some adults

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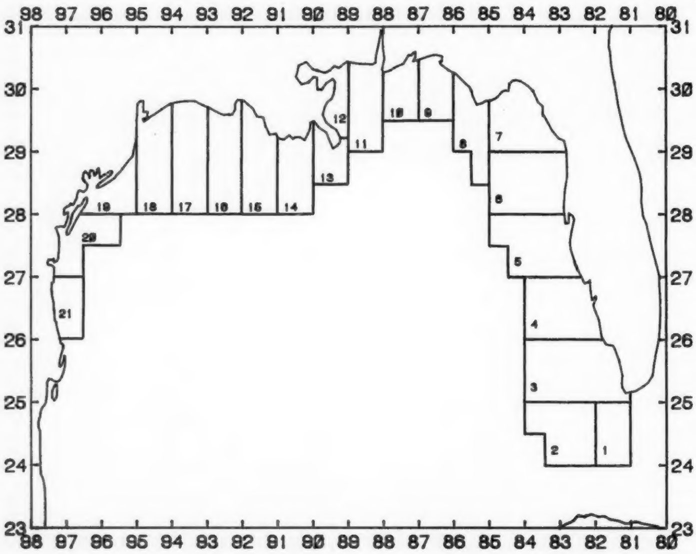

Figure 1.—Statistical subareas in the U.S. Gulf of Mexico used for reporting shrimp landings and effort (in Patella, 1975, after Kutkuhn, 1962).

taken with many juveniles may have been included inadvertently. Frequency of this type misrepresentation remains unknown but was probably not substantial, as catches usually consisted of one size class.

Two estimates were computed to indicate relative abundance: 1) Number of fish per hour of trawling and 2) number of fish per hectare. The number of fish per hour of trawling was determined by dividing the number of fish caught by the number of hours fished. This method assumes a linear relationship between the number of fish caught and number of hours fished (i.e., in a given location, twice as many fish are caught in a 2-hour tow as a 1-hour tow with the same net). The number of fish per hectare was determined by dividing the number of fish caught by the number of hectares swept by the trawl. The number of hectares swept was computed using a modification of the method of Roe (1969):

$$ha = \frac{6{,}076.12\,K \times H \times 0.67\,L}{107{,}640}$$

where K is the vessel speed in knots (6,076.12 feet = 1 n.mi.); H is the number of hours fished; L is the headrope length in feet, 0.67 is a constant (an average horizontal trawl opening is about 67 percent of the headrope length[1]); and a hectare (ha) = 107,640 square feet. This formula assumes an equal catchability coefficient for snapper regardless of trawl size.

Data were analyzed similarly for both sources. Indices of relative abundance were summarized by depth, month, year, time of day, and statistical subareas. These subareas were those used in reporting Gulf Coast Shrimp Data (GCSD) and are illustrated in Figure 1 (Patella, 1975). Surface area in hectares for statistical subareas have been computed and reported by Patella, 1975.

Mean numbers of fish per hour and hectare were multiplied by shrimping effort and area in hectares, respectively, to develop catch estimates. Effort data published in GCSD represent interviewed craft only and do not reflect total effort. As about one-third of the shrimp fleet was interviewed[2], the number of days fished was multiplied by three to represent total fleet days fished.

The number of hours fished was estimated by multiplying days fished by 24. Where effort data were not available for subareas, months or depths, effort was estimated from available landings and effort information in adjacent subareas. Effort data by statistical subareas were then used as the base effort estimate for computational purposes. These effort data were used because of their similarity to the effort data reported in the GMFMC Shrimp Management Plan, October 1979 (4,717,368 hours, effort summation by statistical subarea vs. 4,596,307 hours, effort reported in GMFMC Shrimp Management Plan, October 1979).

No adjustments were made to compensate for differences in the size of trawl nets used by the commercial shrimp fleet. Relating catch per unit effort (CPUE) to a standard trawl net size would not provide useful information because the CPUE reported in GCSD Report is not similarly standardized. Since commercial data for this study were obtained from the shrimp fleet, we assumed the various net sizes sampled adequately represented those of the entire fleet. The estimated number of fish per hectare does compensate for net size as headrope length was included in the formula for the area swept by the trawl.

Results

Commercial data for 1972 through 1981 included a 10-year total of 2,856 stations, fished for 11,665.3 hours (Table 1). Fishing effort for 1972, 1973, 1974, and 1979 was less than 100 hr yearly, while all other years ranged from 401.3 to 4,821.9 hr, with a mean of 1,926.7 hr (Table 1). Monthly commercial fishing effort ranged from 345.0 to 2,681.7 hr (Table 2) and hourly data ranged from 139.2 to 1,143.9 hr (Table 3). Depths to 50 fm were fished, with 98% of the commercial effort at less than 30 fm (Table 4). Data were also separated into statistical subareas (Table 5),

[1]John Watson, NMFS Pascagoula Laboratory, Pascagoula, Miss. Personal commun.

[2]Guy Davenport, Fishery Information Management Division (FIMD), NMFS Miami Laboratory, Miami, Fla. Personal commun.

with only subareas 5, 9, and 10 showing no commercial fishing effort. Fewer than 100 hours were fished in subareas 6, 7, and 8, and effort in the other subareas ranged from 102.2 to 2,198.8 hours.

Resource assessment data for 1972 through 1983 included a 12-year total of 17,589 stations, fished for 3,630.5 hours (Table 1). Total hours fished per year ranged from 125.6 to 543.2 (Table 1), by month from 42.2 to 817.0 hours (Table 2), and by hour from 94.0 to 225.7 (Table 3). Depths from 5 to 50 fm were sampled, with 81 percent of the effort expended at depths of 30 fm or less (Table 4). Effort data by statistical subareas for resource assessment cruises are listed in Table 5 and show most effort expended between Mobile Bay, Ala. (subarea 11) to Morgan City, La. (subarea 15).

Table 1.—Annual summary statistics of juvenile red snapper captured in the Gulf of Mexico by NMFS resource assessment surveys from 1972 to 1983 and by commercial shrimp trawlers from 1972 to 1981.

Year	No. of stations	Hours fished	Frequency of occurrence	No. of individuals	Wt. (kg)	No. per hour	Kg per hour	No. per hectare	Mean wt. per individual (g)	Mean length of headrope (ft)
Resource survey data										
1972	700	125.6	287	4,224	100.2	33.622	0.798	6.942	23.6	42.7
1973	1,184	204.9	229	1,341	41.3	6.544	0.201	1.400	30.8	41.2
1974	2,398	464.5	190	1,266	39.0	2.725	0.084	0.601	30.8	40.0
1975	2,300	508.6	317	2,383	71.2	4.686	0.140	0.945	29.9	43.7
1976	2,368	543.2	280	2,273	85.7	4.184	0.158	0.895	37.6	41.2
1977	1,346	383.4	272	2,439	88.4	6.362	0.231	1.361	36.3	41.2
1978	1,094	182.3	137	2,803	146.5	15.379	0.804	3.388	52.2	40.0
1979	765	127.8	157	829	15.9	6.485	0.124	1.429	19.1	40.0
1980	1,627	324.5	439	3,631	83.0	11.190	0.256	2.465	22.7	40.0
1981	1,636	338.2	396	3,688	117.3	10.905	0.347	2.403	31.8	40.0
1982	1,505	293.2	370	3,210	132.0	10.949	0.450	2.412	41.3	40.0
1983	666	134.3	79	420	26.4	3.127	0.196	0.689	62.6	40.0
Commercial data										
1972	11	5.9	0	0	0.0	0.000	0.000	0.000	0.00	45.5
1973	27	29.2	4	274	22.7	9.384	0.776	1.838	82.5	45.0
1974	99	68.8	13	138	8.2	2.007	0.119	0.395	59.0	44.8
1975	119	401.3	7	186	15.4	0.464	0.038	0.071	83.0	57.5
1976	395	1,436.4	27	2,943	190.1	2.049	0.132	0.401	64.4	45.0
1977	316	1,419.2	20	1,197	0.0	0.843	0.000	0.000	0.0	53.9
1978	1,049	4,821.9	34	2,459	113.1	0.510	0.024	0.076	45.8	57.2
1979	2	1.0	0	0	0.0	0.000	0.000	0.000	0.0	40.0
1980	598	2,357.2	66	3,867	142.2	1.640	0.060	0.208	36.7	69.5
1981	240	1,124.4	46	2,509	144.3	2.231	0.128	0.273	57.6	72.2

Table 2.—Monthly summary statistics of juvenile red snapper captured in the Gulf of Mexico by NMFS resource assessment surveys from 1972 to 1983 and by commercial shrimp trawlers from 1972 to 1981.

Year	No. of stations	Hours fished	Frequency of occurrence	No. of individuals	Wt. (kg)	No. per hour	Kg per hour	No. per hectare	Mean wt. per individual (g)	Mean length of headrope (ft)
Resource survey data										
Jan.	1,098	185.6	133	1,073	42.6	5.781	0.230	1.274	39.9	40.0
Feb.	253	42.2	34	229	6.2	5.420	0.146	1.196	26.8	40.0
Mar.	1,492	302.0	204	1,859	79.5	6.156	0.263	0.166	42.6	40.3
Apr.	1,957	339.7	257	1,448	63.0	4.263	0.186	0.842	43.5	44.6
May	319	71.6	59	378	10.0	5.278	0.139	1.163	26.3	40.0
June	1,737	380.5	153	1,815	65.9	4.770	0.173	1.048	36.3	40.1
July	1,066	255.9	87	757	46.8	2.958	0.183	0.634	61.7	41.1
Aug.	932	208.5	72	503	11.3	2.413	0.054	0.532	22.7	40.0
Sept.	724	353.1	254	3,393	69.9	9.610	0.198	1.942	20.4	43.6
Oct.	3,016	571.2	797	9,022	327.2	15.794	0.573	3.446	36.3	40.4
Nov.	4,626	817.0	1,048	7,744	218.4	9.478	0.267	2.083	28.1	40.1
Dec.	369	103.2	55	286	6.4	2.770	0.062	0.576	22.2	42.4
Commercial data										
Jan.	64	345.0	0	0	0.0	0.000	0.000	0.000	0.0	63.2
Feb.	122	589.2	2	12	0.5	0.020	0.001	0.003	45.4	63.1
Mar.	67	354.7	4	49	3.0	0.138	0.009	0.018	62.1	68.7
Apr.	103	597.9	0	0	0.0	0.000	0.000	0.000	0.0	59.0
May	142	588.9	4	127	5.6	0.216	0.010	0.034	44.5	55.2
June	200	724.8	4	68	3.4	0.094	0.005	0.014	50.8	59.8
July	317	800.0	34	1,782	104.5	2.227	0.131	0.338	58.5	58.1
Aug.	203	741.9	36	1,476	87.2	1.989	0.117	0.328	59.0	53.5
Sept.	488	1,623.0	33	2,065	52.9	1.272	0.033	0.188	25.6	59.5
Oct.	563	2,681.7	49	4,216	163.9	1.572	0.061	0.236	39.0	58.8
Nov.	373	1,728.3	28	2,553	166.6	1.477	0.097	0.224	65.3	58.0
Dec.	214	890.0	23	1,225	48.2	1.376	0.054	0.226	39.5	53.7

Data collected from both commercial and resource assessment cruises indicated red snapper was the major snapper species caught by trawls in the U.S. Gulf of Mexico (Table 6). The gray snapper, *L. griseus*, was the only other shallow-water snapper captured by commercial shrimp trawlers. Lane snappers, *L. synagris*, were generally taken by trawlers outside the depth range of juvenile red snapper. They were most frequently caught between Tampa and Tortugas, Fla., on live sponge bottom areas which were not extensively fished by the commercial shrimp fleet. Other snappers infrequently caught included the yelloweye, *L. vivanus*, and blackfin, *L. buccanella*, but they were caught in deep water well outside the depth range of juvenile red snapper.

Some data from the Shrimp Fleet By-Catch Study were judged questionable because of small sample size. From 1972 to 1974, and in 1979, little fishing occurred, with only 6, 29, 69 and 1 hours fished in each year, respectively. Annually, juvenile red snapper were caught by commercial shrimpers at a mean rate of 8 percent of the stations sampled per year (range, from 0 to 19 percent of the stations). The resource assessment data provided a better picture of the susceptibility of juvenile red snapper to trawling gear, probably because of the survey's random selection of stations rather than the directed sampling of the commercial fleet. Juvenile red snapper were caught at a mean rate of 20 percent of the resource assessment stations sampled per year (range, from 8 to 41 percent of the stations).

Initial total annual estimates of juvenile red snapper caught by the U.S. Gulf shrimp fleet were highly variable among years, ranging from 2.2 to 44.2 million

Table 3.—Hourly summary statistics of juvenile red snapper captured in the Gulf of Mexico by NMFS resource assessment surveys from 1972 to 1983 and by commercial shrimp trawlers from 1972 to 1981.

Time of day	No. of stations	Hours fished	Frequency of occurrence	No. of individuals	Wt. (kg)	No. per hour	Kg per hour	No. per hectare	Mean wt. per individual (g)	Mean length of headrope (ft)
Resource survey data										
0100	816	211.2	143	1,270	35.2	6.014	0.166	1.287	27.7	41.2
0200	795	196.9	159	1,825	72.2	9.269	0.367	1.988	39.5	41.1
0300	736	170.1	153	1,366	42.8	8.031	0.252	1.730	31.3	40.9
0400	750	159.5	155	1,264	30.7	7.924	0.192	1.716	24.0	40.7
0500	769	147.2	157	1,527	52.4	10.374	0.356	2.252	34.5	40.6
0600	691	123.5	129	1,029	28.3	8.335	0.229	1.804	27.7	40.7
0700	714	121.3	110	714	20.3	5.885	0.167	1.275	28.6	40.7
0800	709	121.9	116	719	19.9	5.898	0.163	1.284	27.7	40.5
0900	650	110.3	108	702	20.7	6.363	0.188	1.382	29.5	40.6
1000	678	114.9	105	1,714	91.9	14.915	0.800	3.238	53.5	40.6
1100	688	120.1	119	754	30.0	6.277	0.249	1.359	39.9	40.7
1200	657	113.6	98	573	19.0	5.045	0.167	1.090	33.1	40.8
1300	643	113.5	88	980	41.5	8.637	0.366	1.874	42.2	40.6
1400	644	111.3	95	680	19.5	6.108	0.175	1.320	28.6	40.8
1500	676	118.4	110	575	14.6	4.856	0.123	1.049	25.4	40.8
1600	671	118.7	116	809	29.6	6.814	0.249	1.479	36.7	40.6
1700	523	94.0	89	545	15.4	5.797	0.164	1.259	28.1	40.6
1800	786	148.9	140	1,311	36.8	8.807	0.247	1.883	28.1	41.2
1900	728	153.2	125	971	47.8	6.340	0.312	1.362	49.4	41.0
2000	847	225.7	161	1,628	40.3	7.215	0.179	1.524	24.9	41.7
2100	886	209.5	175	1,810	49.2	8.640	0.235	1.848	27.2	41.2
2200	876	218.5	181	2,001	61.5	9.159	0.282	1.954	30.8	41.3
2300	855	223.7	180	2,279	91.1	10.188	0.407	2.174	39.9	41.3
2400	801	184.8	141	1,461	36.1	7.907	0.195	1.695	24.9	41.1
Commercial data										
0100	133	655.4	17	1,791	86.8	2.733	0.132	0.427	48.5	56.4
0200	187	790.5	16	1,606	69.9	2.032	0.088	0.348	43.5	51.5
0300	124	466.9	4	160	1.9	0.343	0.004	0.051	11.8	59.5
0400	76	221.0	6	67	2.5	0.303	0.011	0.045	37.2	59.6
0500	37	139.2	1	22	0.0	0.158	0.000	0.021	0.0	67.2
0600	128	472.4	12	378	15.0	0.800	0.032	0.112	39.5	62.9
0700	250	871.9	9	271	11.9	0.311	0.014	0.045	44.0	60.8
0800	126	527.1	8	251	11.1	0.476	0.021	0.072	44.0	58.4
0900	90	323.2	4	116	3.7	0.359	0.011	0.053	32.2	59.5
1000	96	342.0	1	10	0.4	0.029	0.001	0.004	45.4	57.0
1100	86	336.8	4	42	2.9	0.125	0.009	0.018	68.0	59.9
1200	104	422.9	0	0	0.0	0.000	0.000	0.000	0.0	62.0
1300	88	350.3	3	242	15.0	0.691	0.044	0.104	64.0	58.7
1400	62	213.7	4	576	12.1	2.695	0.056	0.420	20.9	56.6
1500	49	197.3	0	0	0.0	0.000	0.000	0.000	0.0	58.5
1600	30	145.1	2	241	2.1	1.661	0.014	0.240	8.6	61.1
1700	64	358.7	3	62	5.0	0.173	0.014	0.023	81.2	65.2
1800	134	800.3	19	1,890	100.9	2.362	0.126	0.364	53.5	57.2
1900	163	875.8	20	1,127	57.6	1.287	0.066	0.202	51.3	56.2
2000	269	1,143.9	33	2,297	130.3	2.008	0.114	0.297	56.7	59.6
2100	207	737.2	22	1,473	62.9	1.998	0.085	0.333	42.6	52.9
2200	91	258.4	11	393	27.8	1.521	0.108	0.235	70.8	57.1
2300	99	297.1	6	319	7.3	1.074	0.024	0.167	22.7	56.6
2400	163	718.3	12	239	8.3	0.333	0.012	0.047	34.9	61.9

Table 4.—Depth summary statistics of juvenile red snapper captured in the Gulf of Mexico by NMFS resource assessment surveys from 1972 to 1983 and by commercial shrimp trawlers from 1972 to 1981.

Depth in fathoms	No. of stations	Hours fished	Frequency of occurrence	No. of individuals	Wt. (kg)	No. per hour	Kg per hour	No. per hectare	Mean wt. per individual (g)	Mean length of headrope (ft)
Resource survey data										
0-10	5,227	948.0	460	4,279	147.5	4.513	0.156	0.990	34.5	40.2
11-20	5,728	1,230.7	1,681	16,898	517.9	13.731	0.421	2.874	30.6	42.1
21-30	3,424	771.7	805	5,857	212.7	7.589	0.276	1.652	36.3	40.5
31-40	2,181	498.8	179	1,381	65.8	2.768	0.132	0.604	47.6	40.4
41-50	1,027	180.9	28	92	3.2	0.508	0.018	0.111	34.8	40.3
Commercial data										
0-10	1,752	6,951.8	62	3,213	114.3	0.462	0.016	0.065	35.6	62.6
11-20	786	3,399.1	132	8,918	457.3	2.624	0.135	0.462	51.3	50.1
21-30	258	1,096.8	23	1,442	64.4	1.315	0.059	0.212	44.7	54.7
31-40	58	216.9	0	0	0.0	0.000	0.000	0.000	0.0	60.1
41-50	2	0.7	0	0	0.0	0.000	0.000	0.000	0.0	55.0

individuals. These estimates were calculated by multiplying the mean annual shrimping effort (4,717,368 hours) by the lowest (0.46) and highest (9.38) annual CPUE values from the commercial discard data (Table 1). This variability probably resulted from different levels of fishing effort within specific areas in the Gulf. Less variable estimates of the catch were obtained by calculating estimates separately for each state before combining them into a total estimate (Table 7).

Fewer juvenile red snapper were caught from January through June, with most taken from September to November (Table 2 and Figure 2). More juvenile red snapper were caught during resource assessment cruises throughout the year than on commercial shrimping trips. This difference probably reflected methodology differences in (random sampling vs. directed fishing) rather than seasonal distribution patterns.

Juvenile red snapper were captured in all months except January and April on commercial shrimp trawlers. The greatest catches by both commercial shrimpers and during resource assessment cruises were from September through November (Table 2 and Figure 2). The frequency of monthly juvenile red snapper captures from the commercial shrimp discard data ranged from 0 to 18 percent of the stations occupied with a mean of 6 percent. Resource assessment data, however, indicated a broader distribution of juveniles, with frequency of capture ranging from 8 to 35 percent of the stations occupied, and a mean of 16 percent.

Estimated monthly catches of juveniles are shown in Table 8, with means summed to obtain an annual estimate. Monthly captures based on commercial shrimp discard data were highest from July through November, and lowest from January through April (Table 8).

Analysis of the commercial shrimp trawler data by statistical subarea showed most captures off Texas and least off the west coast of Florida (Table 5 and Figure 3). Although considerable effort was expended in subareas 1 through 4, representing 93 percent of the total Florida commercial shrimping effort, few juve-

Table 5.—Summary statistics by subarea of juvenile red snapper captured in the Gulf of Mexico by NMFS resource assessment surveys from 1972 to 1983 and by commercial shrimp trawlers from 1972 to 1981.

Stat. subarea	No. of stations	Hours fished	Frequency of occurrence	No. of indi-viduals	Wt. (kg)	No. per hour	Kg per hour	No. per hectare	Mean wt. per indi-vidual (g)	Mean length of head-rope (ft)
Resource survey data										
1	0	0.0	0	0	0.0	0.000	0.000	0.000	0.0	0.0
2	42	33.7	1	10	0.0	0.297	0.000	0.047	0.0	55.2
3	39	6.5	0	0	0.0	0.000	0.000	0.000	0.0	40.0
4	39	6.5	0	0	0.0	0.000	0.000	0.000	0.0	40.0
5	49	8.2	0	0	0.0	0.000	0.000	0.000	0.0	40.0
6	85	14.1	0	0	0.0	0.000	0.000	0.000	0.0	40.0
7	50	8.3	0	0	0.0	0.000	0.000	0.000	0.0	40.0
8	25	4.5	0	0	0.0	0.000	0.000	0.000	0.0	40.0
9	67	14.1	2	6	0.4	0.424	0.032	0.093	75.7	40.0
10	413	70.7	65	349	8.6	4.935	0.122	1.088	24.5	40.0
11	6,095	1,165.6	1,543	15,059	447.2	12.919	0.384	2.731	29.5	41.7
12	208	34.5	3	5	0.1	0.145	0.003	0.032	18.1	40.0
13	2,061	363.3	201	1,266	38.4	3.485	0.106	0.766	30.4	40.1
14	4,081	727.8	610	5,872	263.5	8.069	0.362	1.756	44.9	40.5
15	2,740	784.2	331	2,152	51.5	2.744	0.066	0.588	24.0	41.1
16	421	77.3	104	728	26.3	9.418	0.340	2.075	36.3	40.0
17	288	83.0	59	519	19.2	6.253	0.231	1.378	37.2	40.0
18	269	64.0	81	1,138	46.4	17.777	0.726	3.918	40.8	40.0
19	147	37.8	43	512	14.2	13.533	0.375	2.984	27.7	40.0
20	127	38.1	57	481	12.2	12.608	0.321	2.782	25.4	40.0
21	217	55.9	42	371	18.1	6.639	0.325	1.462	49.0	40.0
Commercial data										
1	36	102.2	0	0	0.0	0.000	0.000	0.000	0.0	67.5
2	125	490.5	1	9	0.0	0.018	0.000	0.003	0.0	57.0
3	24	115.0	0	0	0.0	0.000	0.000	0.000	0.0	57.9
4	81	194.1	6	164	0.0	0.845	0.000	0.139	0.0	53.6
5	0	0.0	0	0	0.0	0.000	0.000	0.000	0.0	0.0
6	16	43.5	0	0	0.0	0.000	0.000	0.000	0.0	60.0
7	4	5.6	0	0	0.0	0.000	0.000	0.000	0.0	43.0
8	15	18.0	0	0	0.0	0.000	0.000	0.000	0.0	45.7
9	0	0.0	0	0	0.0	0.000	0.000	0.000	0.0	0.0
10	0	0.0	0	0	0.0	0.000	0.000	0.000	0.0	0.0
11	162	502.4	12	273	21.0	0.543	0.042	0.077	77.1	62.2
12	62	187.1	2	17	1.0	0.091	0.005	0.010	58.5	82.2
13	209	579.8	30	1,350	56.8	2.328	0.098	0.357	42.2	57.4
14	113	385.4	3	129	7.3	0.335	0.019	0.032	56.2	61.2
15	295	957.7	6	188	4.0	0.196	0.004	0.028	21.3	61.3
16	188	921.6	15	263	13.6	0.285	0.014	0.038	51.7	66.6
17	172	746.5	8	421	36.2	0.564	0.048	0.079	86.2	63.2
18	514	2,198.8	17	1,459	100.8	0.664	0.046	0.095	68.9	61.6
19	344	1,637.5	43	2,772	142.2	1.693	0.087	0.246	51.2	60.7
20	348	1,847.3	51	4,148	184.3	2.245	0.100	0.461	44.4	42.9
21	140	740.3	23	2,380	68.7	3.379	0.097	0.662	29.0	45.0

Table 6.—Species of snapper captured by NMFS resource assessment surveys, 1972-83, and by commercial shrimp trawlers in the Gulf of Mexico, 1972-81.

Species	Commercial: No. of indi-viduals	Commercial: Percent of total	Resource: No. of indi-viduals	Resource: Percent of total
Red snapper, *L. campechanus*	45,487	98	115,168	91
Lane snapper, *L. synagris*	942	2	10,788	9
Gray snapper, *L. griseus*			336	

Table 7.—Mean annual estimate of juvenile red snapper caught by commercial shrimpers in the U.S. Gulf of Mexico from 1972 to 1981. Estimates are based on (NMFS, FIMD) reports of average hours fished off identified states, multiplied by the mean number caught per hour by the commercial fleet operating off the respective states.

State	Total hours fished	Mean catch (no./hr.)	No. of individuals caught
Florida	707,605	0.096	67,390
Alabama/Miss.	330,215	0.211	69,676
Louisiana	2,169,989	0.742	1,610,132
Texas	1,509,558	1.995	3,011,568
Total	4,717,368		4,759,306

nile red snapper were caught.

Across the Gulf within statistical subareas, the frequency of red snapper occurrence in commercial catches ranged from 0 to 16 percent. Mean frequency of occurence by state area was as follows: Florida, 0.9 percent; Alabama and Mississippi combined, 3.4 percent; Louisiana, 6.5 percent; and Texas, 11.7 percent. Florida (subareas 1 to 9), in which 15.0 percent of the total commercial shrimping effort was expended, yielded only 1.4 percent of the juvenile red snapper catch, probably reflecting the paucity of suitable trawling areas. Total effort and juvenile red snapper catch from commercial shrimp trawlers was also low off

Table 8.—Mean monthly estimates of juvenile red snapper caught in the U.S. Gulf of Mexico by commercial shrimp trawlers from 1972 to 1981. Estimates were calculated using mean number caught per hour of trawling multiplied by the reported interviewed shrimping effort (NMFS, FIMD). Shrimp days were based on interviewed craft; therefore, final estimates were multiplied by 3 to reflect total effort and catch.

Month	Inshore (0-20 fm): Shrimp days	Inshore (0-20 fm): Percent effort	Offshore (20+ fm): Shrimp days	Offshore (20+ fm): Percent effort	Total: Shrimp days	Total: Percent effort	Estimated numbers: Mean number red snapper per hour	Estimated numbers: Number caught
January	1,298	2.3	746	8.2	2,044	3.1	0.00	0
February	1,298	2.3	818	9.0	2,116	3.2	0.02	1,016
March	1,580	2.8	646	7.1	2,226	3.4	0.14	7,479
April	2,144	3.8	446	4.9	2,590	4.0	0.00	0
May	6,320	11.2	464	5.1	6,784	10.3	0.22	35,820
June	8,407	14.9	246	2.7	8,653	13.2	0.09	18,690
July	6,094	10.8	500	5.5	6,594	10.1	2.23	352,911
August	6,658	11.8	1,073	11.8	7,731	11.8	1.99	369,232
September	6,884	12.2	1,137	12.5	8,021	12.2	1.27	244,480
October	7,335	13.0	891	9.8	8,226	12.6	1.57	309,956
November	5,586	9.9	1,073	11.8	6,659	10.2	1.48	236,528
December	2,821	5.0	1,046	11.5	3,867	5.9	1.36	128,075
Total	169,275		27,258		196,533			5,112,561
Percent	86		14					

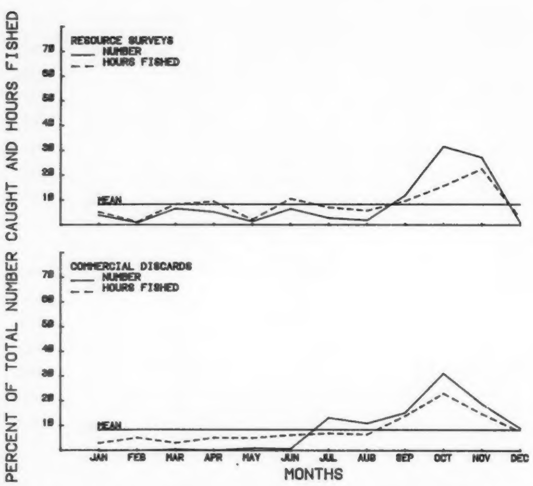

Figure 2.—Monthly catch of juvenile red snapper and sampling effort expressed as percentage of the total number caught and hours fished for commercial discard and resource assessment data; mean value represents average percent of total number caught for all months.

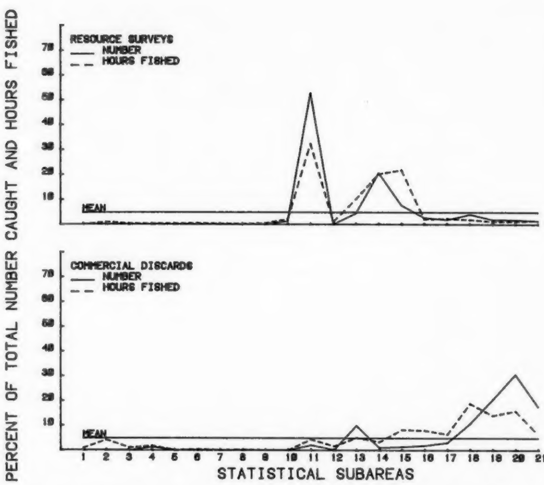

Figure 3.—Catch of juvenile red snapper and sampling effort by statistical subareas expressed as percentage of the total number caught and hours fished for commercial discard and resource assessment data; mean value represents average percent of total number caught for all statistical subareas.

Table 9.—Mean inshore-offshore estimates of juvenile red snapper caught within statistical subareas by commercial shrimp trawlers in the U.S. Gulf of Mexico from 1972 to 1981. Estimates were calculated using mean number caught per hour of trawling multiplied by the reported interviewed shrimping effort (NMFS, FIMD). Shrimp days were based on interviewed craft; therefore, final estimates were multiplied by 3 to reflect total effort and catch.

	Inshore (0-20 fm)			Offshore (20+ fm)			Combined in-offshore
Statistical subarea	Shrimping days	No. of red snapper/hr	Total no. caught	Shrimping days	No. of red snapper/hr	Total no. caught	Total no. caught
1	243	0.00	0	2	0.00	0	0
2	4,003	0.02	1,921	452	0.02	217	2,138
3	2,255	0.00	0	27	0.00	0	0
4	930	0.85	18,972	28	0.85	562	19,534
5	554	0.00	0	4	0.00	0	0
6	544	0.00	0	0	0.00	0	0
7	549	0.00	0	7	0.00	0	0
8	439	0.00	0	11	0.00	0	0
9	51	0.00	0	2	0.00	0	0
10	555	0.00	0	16	0.00	0	0
11	2,487	0.54	32,232	68	0.54	885	33,117
12	1,266	0.09	2,735	5	0.09	13	2,748
13	5,140	2.33	287,403	1383	2.33	77,313	364,716
14	7,601	0.34	62,027	490	0.34	4,001	66,028
15	6,982	0.20	33,514	855	0.20	4,102	37,616
16	3,544	0.29	24,668	810	0.29	5,639	30,307
17	3,292	0.56	44,241	36	0.56	488	44,729
18	5,020	0.66	79,520	830	0.66	13,140	92,660
19	6,456	1.69	261,868	1,219	1.69	49,449	311,317
20	2,461	2.25	132,890	1,332	2.25	71,950	204,840
21	2,054	3.38	166,616	1,516	3.38	122,974	289,590
Total	169,728		3,445,821	27,279		1,052,199	4,498,020
Percent	77			23			

Alabama and Mississippi. In this area, 7 percent of the Gulf commercial shrimping effort was expended but only 1.5 percent of the juveniles were caught. Commercial shrimping effort east of the Mississippi River delta represented 22.0 percent of the total Gulf effort, but yielded only 3.0 percent of the juvenile red snapper catch.

West of the Mississippi Delta, juvenile red snapper were taken primarily in subareas 13 (Louisiana) and 19 to 21 (Texas) by commercial shrimp trawlers (Fig. 3). Commercial shrimping effort off Louisiana represented 46 percent of the total Gulf effort, where 34 percent of the juvenile red snappers were caught. Texas shrimpers caught 63 percent of the juveniles, but expended only 32 percent of the total shrimping effort (Tables 7 and 9). Resource assessment data also showed that the highest densities of red snapper (mean number of juveniles per hectare) were west of the delta, primarily off Texas (Table 5 and Figure 4).

Within subareas, differences also were noted between inshore (0-20 fm) and offshore (20+ fm) depths (Table 9). The highest inshore and offshore estimates of juveniles were off Texas (56 and 73 percent, respectively, of the total estimated numbers caught). Juvenile red snapper

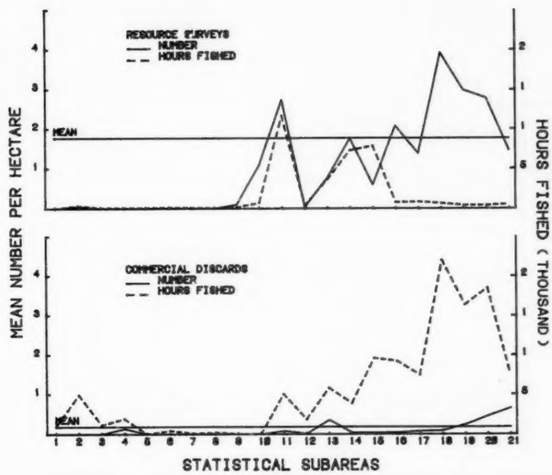

Figure 4.—Catch of juvenile red snapper and sampling effort by statistical subareas expressed as mean number per hectare (density) and hours fished for commercial discard and resource assessment data; mean catch represents average number caught for all statistical subareas.

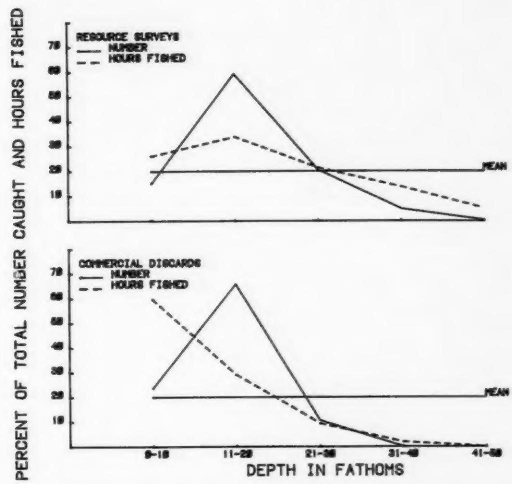

Figure 5.—Catch of juvenile red snapper and sampling effort by depth expressed as percentage of the total number caught and hours fished for commercial discard and resource assessment data; mean catch represents average percent of total number caught for all depths.

abundance by depth zone was greatest in 11-20 fm in both commercial shrimp discards and resource assessment data (Table 4 and Figure 5). Juveniles were not caught at depths greater than 31 fm by commercial shrimp vessels, and at these depths they represented only 5 percent of the total resource assessment catch. Commercial shrimp discard data showed 66 percent of the snapper were caught in 11-20 fm, but only 29 percent of the effort was expended in this stratum. Resource assessment data showed a similar pattern, with 59 percent of the individuals and 34 percent of the effort expended in 11-20 fm. Both commercial shrimp discard and resource assessment data showed the highest frequency of occurrence in the 11-20 fm depth range with the second highest in 21-30 fm, followed by the 0-10 fm range. Few juveniles were caught at other depths.

Hourly captures of juveniles based on resource assessment data were fairly uniform throughout the day. Commercial hourly catches, however, were larger at night (Table 3) due in part to hourly differences in fishing efforts (Figure 6). Fre-

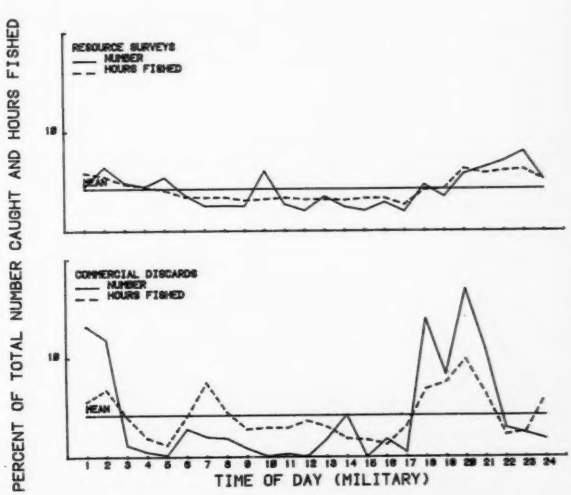

Figure 6.—Catch of juvenile red snapper and sampling effort by hour expressed as percentage of the total number caught and hours fished for commercial discard and resource assessment data; mean catch represents average percent of total number caught for all hours.

quency of occurrence for hourly catches of juvenile red snapper ranged from 14 to 21 percent, with a mean of 18 percent in the resource assessment data; whereas, the commercial shrimp discard data showed a range from 0 to 14 percent, with a mean of 6 percent.

Discussion

Results of this study generally agree with previous estimates of the catch of juvenile red snapper in the Gulf of Mexico. Bradley and Bryan (1976) noted that lower catch rates were recorded by commercial trawlers than by resource assessment cruises, with the mean size of red snapper on commercial trawlers seldom exceeding 200 mm FL. Juveniles were caught along the entire Texas coast, with few taken inside 10 fm or outside 35 fm. Red snapper caught on NMFS resource assessment cruises were also principally juveniles (<200 mm FL) and associated with commercial shrimping depths. This is in agreement with Bradley and Bryan's (1976) conclusion that areas of young snapper abundance coincide with shrimping grounds. Trawl surveys conducted along the Texas and Louisiana coasts (Gunter, 1945; Miller, 1965; Chittenden and McEachran, 1976; Ragan et al., 1978) recorded few, if any, red snapper taken inside 10 fm.

Juvenile red snapper appear to move offshore in colder months, returning inshore in warmer months. This pattern was noted in both the commercial shrimp discard and resource assessment cruise data (Table 10), with the most pronounced difference occurring between spring and summer cruises. During spring and fall cruises, 86 percent of the captures occurred from 11 to 30 fm, which was similar to that reported by Bradley and Bryan (1976). In summer months, 93 percent of the captures occurred at depths to 20 fm (Table 10).

Juvenile red snapper were captured during all months as reported in previous studies. The capture of juveniles 34-70 mm SL off Texas in January, March, June through October, and December (Bradley and Bryan, 1976); 60-70 mm FL off Louisiana and Mississippi in March/April; and 30-40 mm FL in October/November in this study indicates a

Table 10.—Juvenile red snapper caught on resource assessment surveys in the U.S. Gulf of Mexico (1972-1983) by depth. Numbers and percentages are composites from several surveys and represent fish less than 200 mm FL.

Depth (fm)	Spring		Summer		Fall	
	No.	Pct.	No.	Pct.	No.	Pct.
0-10	24	3	397	37	135	10
11-20	336	42	604	56	664	49
21-30	355	44	62	6	508	37
31-40	82	10	12	1	57	4
41-50	11	1	0	0	1	0
0-20	405	45	1,001	93	1,552	62
20+	503	55	74	7	923	38

more protracted spawning period throughout the U.S. Gulf of Mexico than reported by Mosely (1966) and Futch and Bruger (1976). Spawning peaks reported in July/August by Mosely (1966) and August/September by Futch and Bruger (1976) coincide with our capture of the highest numbers of juveniles taken from September through November (Table 2).

Estimates of the number of juvenile red snapper caught by commercial shrimp trawlers based on the commercial discard data are listed in Tables 7 to 9. Inshore catches were considerably higher than offshore catches, which agrees with the depth distribution of juvenile red snapper (Table 4). Annual catches of juvenile red snapper by the commercial shrimp trawlers were highly variable, ranging from 0.46 to 9.38 individuals per hour of trawling (Table 1). This variation was possibly due to changes in either the distribution of snapper juveniles or environmental conditions.

July through December were months of highest catch rates of juvenile red snapper on the commercial trawlers, but greatest catches on resource assessment cruises were made from September to November (Table 8 and Figure 2). Few juveniles were caught between January and April on either commercial trawlers or during resource assessment activities, but more were taken in all months during resource assessment cruises. Increased capture rates were probably a reflection of the random station selection. Similar monthly trends were reported by Bradley and Bryan (1976).

All inshore estimates of abundance, based on CPUE, were at least 1.35 times higher than offshore estimates (Table 9). These higher inshore estimates agree with the findings of Bradley and Bryan (1976).

The only reported estimate of total juvenile red snappers captured by the U.S. commercial shrimp fleet was in the Fishery Management Plan for reef fish resources of the Gulf of Mexico (GMFMC, 1980). This estimate suggested a mean annual catch of 78 million red snapper per year and was based on NMFS resource assessment cruises off Texas, during which about 15 juvenile red snapper were caught per hour of trawling (Table 5). The CPUE value of 15 per hour was the same as that reported by Bradley and Bryan (1976) for the 16-25 fm depth range off Texas during a Texas Parks and Wildlife Department study of northwestern Gulf of Mexico marine fisheries from 1970 to 1973. However, the mean estimate for all depth ranges in that study was only 5.98 individuals per hour of trawling.

Average Texas catch rates should not be used for the entire U.S. Gulf, as they were considerably higher than for other Gulf states. Mean catch rates of individuals per hour of trawling from resource assessment data for the Gulf were: Florida, 0.08; Mississippi/Alabama, 6.00; Louisiana, 5.99; and Texas, 12.64. Resource assessment data consistently showed higher density and CPUE values than the commercial shrimp discard data (Tables 1 to 5). Mean catch rates of individual juvenile red snapper per hour of trawling from commercial discard data were: Florida, 0.096; Mississippi/Alabama, 0.211; Louisiana, 0.742; and Texas, 1.995.

Estimates of the juvenile red snapper catch reported in this paper were based on the commercial discard data which more realistically represents the commercial shrimpers catch of juvenile red snapper throughout the Gulf than that presented in the GMFMC (1980) Reeffish Management Plan. A similarity between overall estimates computed by year (4.8 million individuals, Table 7), month (5.1 million, Table 8) and statistical subarea (4.5 million, Table 9), and similar inshore-offshore ratios was noted.

Large numbers of snapper are caught by sport and commercial interests off Florida; however, shrimp vessels cannot operate extensively within this habitat, and the impact of the shrimp fishery on red snapper mortality is probably minimal. The maximum impact of commercial shrimping on red snapper stocks appears to be off Texas where 63 percent of the total juvenile captures occurred. The effect of this pressure on adult populations of Gulf red snapper is unknown.

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Evaluation of Demersal Longline Gear off South Carolina and Puerto Rico With Emphasis on Deep-water Reef Fish Stocks

G. MICHAEL RUSSELL, ELMER J. GUTHERZ, and CHARLES A. BARANS

Introduction

There are no definitive studies testing the efficiency of bottom longlines and other line fishing gears applicable to commercial reef fish assessment. Stock assessment techniques for reef fish in the western central Atlantic, Gulf of Mexico and Caribbean Sea have been presented by several authors (Barans, 1982; Cody et al., 1981; Gutherz, 1982; and Nelson and Carpenter, 1968). Target species included groupers (*Epinephelus* spp. and *Mycteroperca* spp.), porgies (*Calamus* spp. and *Pagrus* spp.), snappers (*Etelis oculatus*, *Pristipomoides macrophthalmus*, *P. aquilonaris*, and *Lutjanus* spp.), and sharks. Kawaguchi (1974) concluded in his studies of the Caribbean snapper fishery that bottom longlines were inefficient compared with hand reels, possibly due to the clumped distribution of target species. However, bottom longlines were found to be twice as effective as snapper reels for tilefish, *Lopholatilus chamaeleonticeps*, on mud bottoms off South Carolina (Low et al., 1983). Matlock et al. (In press) has begun studies to define longline gear efficiency for yellowedge grouper and tilefish off Texas.

Fishery independent catch-per-unit-of-effort (CPUE) data are essential to accurately assess abundance of reef fish resources. Objectives of this study were to: 1) Describe standard longline sampling techniques for deepwater reef fish, 2) clarify apparent advantages and disadvantages of both bottom and offbottom longlines, and 3) compare species compositions and catch rates obtained with the two types of longlines.

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Methods

Study Areas

Comparative gear trials were conducted during three cruises in two geographical areas. These studies were conducted aboard the South Carolina Wildlife and Marine Resources Department (SCWMRD) Ship *Oregon*, cruise OE-82-04, 7/29-8/13/82; the NOAA Ship *Oregon II*, Caribbean cruise 129, 8/26-9/30/82; and NOAA Ship *Delaware II*, Caribbean cruise 83-06, 5/25-7/2/83[1]. The *Oregon* sampled in 183-199 m (100-110 fm) east of Charleston, S.C. (lat. 32°44'N, long. 78°06'W.) in a 0.8km^2 area (referred to as the "Charleston Lumps" in this paper). The site consisted of rock habitat with 40°-50° slopes and 12-26 m of relief. Flattened boulders up to 2 m wide were located near the ridge tops. These boulders appeared to move downslope after becoming undermined and breaking off. Steep ridges were separated by gullies and/or interspersed among rubble slopes. Gullies were composed of compressed foraminifera and shell hash with the appearance of sand. Often the "sand"/shell hash was in dune-like formations.

[1]Cruise reports are available through G. Michael Russell, NMFS Pascagoula Laboratory, P. O. Box 1207, Pascagoula, MS 39568.

The Caribbean study area sampled by the NOAA Ships *Oregon II* and *Delaware II* included the west and north coast of Puerto Rico and the north coasts of Culebra and St. Thomas Islands. Fishing depths were between 69 and 589 m (38-324 fm); however, the majority of effort occurred between 183 and 457 m (100-259 fm). Bottom type consisted of mud, rock, coral and shell. The area was characterized by steep walls with precipitous drops to deeper waters. The upper shelf areas generally consisted of ridge tops along limestone walls.

Sampling Procedures

Bottom and offbottom (Kali poles—Anonymous, 1982) longlines were fished, either joined together or separately, but adjacent to one another. Kali pole hooks on the offbottom longlines were numbered consecutively from top to bottom. Catch data included a tally of hooks with bait, hooks without bait, fish caught, and the hook position on the offbottom longlines where fish were caught.

Specimens lost over the side as well as those brought aboard were recorded by species. Massive tangles often prevented accurate recording of species and numbers caught by hook (Fig. 1). These conditions caused some variation between the published cruise report and the data in this paper.

Fishing Methods and Gear

Bottom longlines consisted of a buoy (Fig. 2) and mainline section (Fig. 3) Buoy lines were constructed with 1.27

cm twisted nylon in 183 m sections. Connections were made with 1.27 cm brummel hooks except where weights were tied to the buoyline with lighter line. This allowed tangled weights to break free (Fig. 2). Buoy poles were counter weighted with a 7 kg weight attached by a "D" ring. The counter weight was attached to a 4.76 cm stainless steel cable 0.3 m long with a quick release snap for easy attachment and removal (Fig. 2).

A 183 m mainline, constructed of 0.97 cm braided nylon with 50 gangions, was used for each set. A gangion consisted of an "AK" snap, a 70 cm length of 91 kg test monofilament, and a #7 circle tuna hook. Gangions were spaced 2 m apart.

Offbottom longlines consisted of a floating mainline (0.97 cm polypropylene rope) with attached Kali poles. These poles (schedule 80 PVC pipe) were 2.44 m in length with reinforcing rod inserted into the lower end and a 10 cm diameter deepwater float wired to the upper end. This maintained the pole's vertical position during fishing operations. Poles were attached by beckets at 7.26 m intervals (Fig. 3). Each pole was equipped with five or six alternating, but equally spaced, gangions.

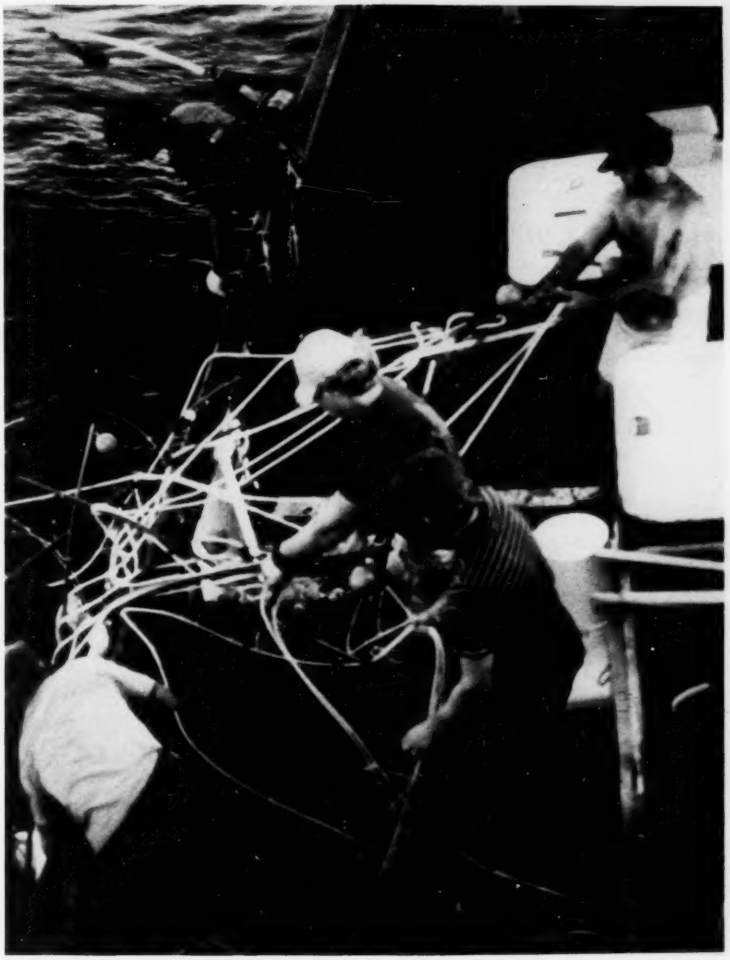

Figure 1.—An offbottom longline Kali pole tangle; clearing these are time consuming and may be dangerous to crew members.

Submersible

Cooperative cruises were conducted by the National Marine Fisheries Service (NMFS), South Carolina Wildlife and Marine Resources Division (SCWMRD), and Harbor Branch Foundation, Inc. to supplement fishery-independent catch data and to assess fish stocks. These cruises utilized the submersible *Johnson Sea-link II* for in situ observations of bottom and offbottom longlines. Fishing attitude and position of the gear relative to the bottom was observed along with species caught. Bottom topography and its effect on longline deployment and retrieval was noted.

Analytical Methods

Prior to comparison of catches between offbottom and bottom longline gear, the data were standardized to number of fish caught per 100 hooks. For comparison of catches by gear the data were log $(X + 1)$ transformed (Elliott, 1977). Three categories were then compared: 1) Total fish between geographical areas; 2) Caribbean shark species, two species of wenchmen, *Pristipomoides aquilonaris* and *P. macrophthalmus*, and all other snappers; and 3) South Carolina blackbelly rosefish, *Helicolenus dactylopterus*, and two species of tilefish (tilefish and blueline tilefish, *Caulolatilus microps*). Transformed and untransformed mean catches and variances of fish per 100 hooks recovered by set were compared by Student's "t" tests and "F" (alpha = 0.05) F-tests (Sokal and Rohlf, 1969). Differences in mean catch between two Kali pole positions (top three hooks vs. bottom two or three hooks, depending on whether it was a five- or six-hook set) on the offbottom longlines were compared by chi-square analysis.

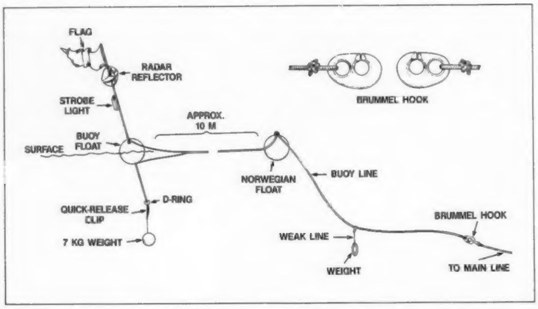

Figure 2.—Diagrammatic representation of buoy system with appropriate connections, lights, and radar reflectors to assist locating the gear.

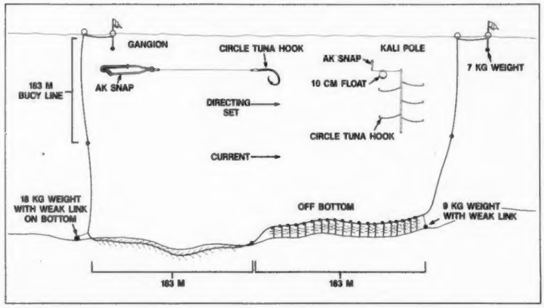

Figure 3.—Diagrammatic representation of a longline set including bottom and offbottom lines and buoy system.

Results

Underwater Observations

Over rough bottom, Kali poles remained upright and free of bottom obstructions appearing as a "picket fence". This upright orientation with the bottom, along with several hooked fish, can be seen in Figure 4. Regardless of longline type, fish captures were habitat specific with few fish caught on bottom with little or no relief. Observations of bottom longlines indicated that difficulty might be expected during retrieval when the lay of the line was among rocks and bottom projections; however, few retrieval difficulties were experienced.

Species Composition

Species diversity from bottom and offbottom longlines was almost identical between similar areas (Table 1). Both longline types caught shark, snapper, and grouper in the Caribbean (*Oregon II*-129 and *Delaware II*-83-06), while blackbelly rosefish, tilefish, and grouper were the most abundant species captured on the Charleston Lumps (*Oregon* OE 82-04).

Pole Position

Fish caught were not evenly distributed among the vertical array of hooks (Fig. 5). This was evident in both Charleston Lumps and Caribbean species groups (Fig. 5). Although the lower group of hooks consistently caught more fish (except grouper and blueline tilefish, *Oregon* 82-04), there were few significant differences in catch rates between upper and lower hook positions (Table 2). Both the total catch and catch of blackbelly rosefish off the Charleston Lumps were significantly greater at the lower hook positions, perhaps indicating a greater abundance of blackbelly rosefish or a close association to the bottom. Small sample sizes for individual species groups, other than blackbelly rosefish, did not allow an analysis of catch trends.

Figure 4.—A Kali pole fishing on the Charleston Lumps with, from top to bottom, snowy grouper, blueline tilefish, and blackbelly rosefish.

Comparison of Catch

The number of fish caught per 100 hooks recovered was consistently greater for bottom longlines than offbottom longlines (Fig. 6, Table 3). Significant differences existed between mean numbers of fish caught for all sharks, blackbelly rosefish, and snapper (1982 data)

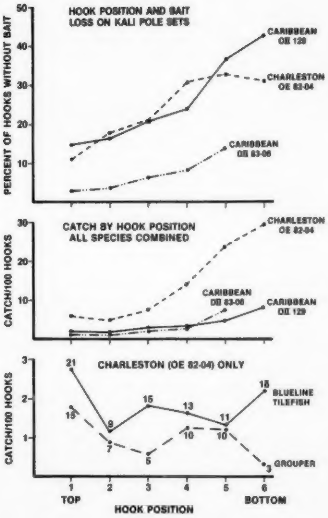

Figure 5.—Bait loss and catch rates by hook positions for Kali poles on offbottom longlines during two comparative cruises in the Caribbean and one off the Charleston Lumps.

Table 1.—Catch composition for three cruises by gear type with numbers of each species caught.

	Bottom longline no.			Offbottom longline no.		
Species	OII 129	DII 83-06	OE-82-04	OII 129	DII 83-06	OE-82-04
	Number of specimens					
Snappers						
Etelis oculatus	17	14	0	8	9	0
Lutjanus buccanella	4	2	0	4	0	0
Lutjanus vivanus	9	6	0	13	8	0
Pristipomoides aquilonaris	23	0	0	18	3	0
Pristipomoides macrophthalmus	69	21	0	53	20	0
Rhomboplites aurorubens	6	0	0	5	2	0
Groupers						
Epinephelus flavolimbatus	3	9	5	4	6	0
Epinephelus guttatus	1	1	0	1	0	0
Epinephelus mystacinus	13	16	0	7	12	0
Epinephelus niveatus	2	1	36	2	1	51
Sharks						
Carcharhinidae	2	0	0	5	0	0
Carcharhinus plumbeus	0	9	0	0	5	0
Centrophorous granulosus	111	0	0	138	0	0
Centrophorous sp.	0	68	0	0	66	0
Dalatias licha	0	1	0	1	0	0
Etmopterus hillianus	0	0	0	2	0	0
Etmopterus virens	0	0	0	0	3	0
Galeus arae	0	0	0	1	0	0
Heptranchias perlo	2	0	0	8	0	0
Hexanchus vitulus	13	9	0	10	7	0
Mustelus canis	49	91	0	42	63	0
Scyliorhinus retifer	1	0	1	0	1	2
Scyliorhinus torrei	0	0	0	1	0	0
Scymnodon sp.	2	0	0	1	0	0
Squalus asper	1	0	0	0	0	0
Squalus cubensis	162	110	0	176	172	0
Tilefish						
Caulolatilus microps	0	0	51	0	0	82
Lopholatilus chamaeleonticeps	0	0	12	0	0	15
Other species						
Caranx lugubris	0	0	0	1	0	0
Chimaera cubana	0	1	0	1	0	0
Conger oceanicus	0	0	0	0	0	1
Conger triporiceps	0	0	0	0	1	0
Gymnothorax moringa	11	5	0	5	7	0
Gymnothorax sp.	1	1	0	0	3	0
Haemulon album	0	1	0	0	0	0
Helicolenus dactylopterus	0	0	415	0	0	531
Hildebrandia flava	1	0	0	1	0	0
Hildebrandia gracilior	0	0	0	3	0	0
Hyperoglype sp.	0	0	0	0	0	2
Ophichthus sp.	9	6	0	1	0	0
Ophichthus gomesii	0	3	0	0	0	0
Polymixia sp.	0	0	0	2	0	0
Pomadasys crocro	0	0	0	1	0	0
Pontinus longispinis	0	0	1	0	0	0
Pontinus rathbuni	0	0	1	0	0	0
Ruvettus pretiosus	0	0	0	1	0	0
Saurida sp.	0	2	0	0	1	0
Seriola dumerili	3	1	2	0	0	0
Seriola rivoliana	2	0	0	0	0	0
Sphyraena barracuda	0	0	0	0	1	0
Urophycis floridanus	0	0	15	0	0	14
Urophycis earlli	0	0	1	0	0	0

Table 2.—Comparison of mean catch rates per 100 hooks recovered by hook position on offbottom longline poles. (NS = nonsignificant, X^2 = chi-square, ** = significant at 0.01 level).

		Catch per 100 hooks									
Cruise	Position	Sharks	Expected	Grouper	Expected	Wenchmen	Expected	Snapper	Expected	Total	Expected
OII 129	Top 3	1.65	2.99	0.09	0.11	0.24	0.42	0.33	0.38	2.33	4.02
	Bottom 3	4.34		0.12		0.59		0.42		5.70	
	X^2	1.21NS		0.01NS		0.10NS		0.01NS		1.41NS	
DII 83-06	Top 3	1.41	2.84	0.12	0.16	0.04	0.19	0.08	0.11	1.72	3.51
	Bottom 2	4.28		0.20		0.34		0.14		5.30	
	X^2	1.45NS		0.02NS		0.24NS		0.02NS		1.82NS	
OE 82-04	Top 3	2.86	11.16	1.53	1.24	1.87	1.82	0.12	0.16	6.26	14.58
	Bottom 3	19.45		0.96		1.76		0.21		22.90	
	X^2	12.33**		0.13NS		0.01NS		0.03NS		9.49**	

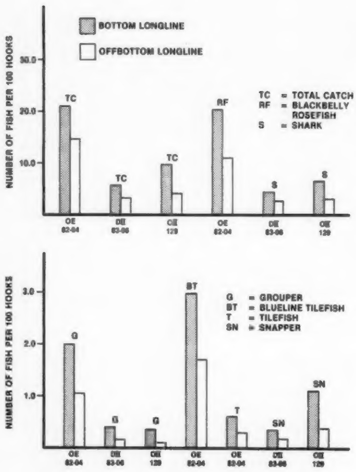

Figure 6.—Catches of grouper, snapper, shark (see Table 1 for species), blueline tilefish, tilefish, blackbelly rosefish, and total catch for bottom and offbottom longlines.

Table 3.—Comparison of means and variances of numbers of fish caught per 100 hooks recovered by bottom longlines (BL) and offbottom longlines (OBL) on three cruises. T = calculated "t" value; F = calculated "F" value; * = significant at 0.05 level; ** = significant at 0.01 level; value in ( ) = df.

			Total fish				Sharks				Snappers			
Cruise and item	Gear	N	$\overline{X}$	S^2	T	F	$\overline{X}$	S^2	T	F	$\overline{X}$	S^2	T	F
Caribbean 1982 (OII 129)														
Untransformed	BL	110	9.8	75.7	6.0**	3.2**	6.4	75.2	3.5**	3.2**	2.4	12.0	4.5**	5.5**
	OBL	110	4.1	23.7	(218)	(109)	3.1	23.5	(218)	(109)	0.8	2.2	(218)	(109)
Transformed	BL	110	0.9	0.2	6.3**	1.3	0.6	0.3	3.0**	1.6**	0.3	0.1	4.1**	2.5**
	OBL	110	0.6	0.1	(218)	(109)	0.4	0.2	(218)	(109)	0.2	0.1	(218)	(109)
Caribbean 1983 (DII 83-06)														
Untransformed	BL	139	5.5	37.9	4.6**	3.8**	4.2	32.1	3.5**	3.2**	0.7	3.6	1.8	3.6**
	OBL	139	2.8	9.9	(276)	(138)	2.3	9.9	(276)	(138)	0.3	1.0	(276)	(138)
Transformed	BL	139	0.6	0.2	3.7**	1.6**	0.5	0.2	3.0**	1.5**	0.1	0.1	1.5	2.1**
	OBL	139	0.4	0.1	(276)	(138)	0.4	0.1	(276)	(138)	0.1	0.0	(276)	(138)
S. Carolina 1982 (OE 82-04)			Total fish				Blackbelly rosefish				Tilefish (all species)			
Untransformed	BL	34	28.1	192.4	4.2**	2.2**	21.2	114.1	4.2**	2.3**	3.7	13.8	1.8	2.1**
	OBL	34	16.0	85.4	(66)	(33)	12.0	50.0	(66)	(33)	2.3	6.8	(66)	(33)
Transformed	BL	34	1.4	0.1	4.2**	1.2	1.3	0.1	4.1**	1.0	0.5	0.1	1.5	1.4**
	OBL	34	1.2	0.1	(66)	(33)	1.0	0.1	(66)	(33)	0.4	0.1	(66)	(33)

Table 4.—Comparison of means and variances of numbers of fish caught per set (not standardized to catch per 100 hooks recovered) by bottom longlines (BL) and offbottom longlines (OBL) on three cruises. T = calculated "t" value; F = calculated "F" value; * = significant at 0.01 level; value in ( ) = df.

			Total fish				Sharks				Snappers			
Cruise and item	Gear	N	$\overline{X}$	S^2	T	F	$\overline{X}$	S^2	T	F	$\overline{X}$	S^2	T	F
Caribbean 1982 (OII 129)														
Untransformed	BL	110	4.7	16.3	0.2	1.7*	3.0	16.6	−0.6	1.6*	1.2	2.7	1.2	1.0
	OBL	110	4.6	27.3	(218)	(109)	3.4	27.3	(218)	(109)	0.9	2.6	(218)	(109)
Transformed	BL	110	0.6	0.1	1.2	1.3	0.4	0.1	−0.1	1.2	0.2	0.1	1.6	1.1
	OBL	110	0.6	0.1	(218)	(109)	0.4	0.2	(218)	(109)	0.2	0.1	(218)	(109)
Caribbean 1983 (DII 83-06)														
Untransformed	BL	139	2.7	9.2	−0.2	1.0	2.0	7.8	−0.5	1.2	0.3	0.8	0.0	1.0
	OBL	139	2.8	9.6	(276)	(138)	2.2	9.7	(276)	(138)	0.3	0.9	(276)	(138)
Transformed	BL	139	0.4	0.1	−0.1	1.0	0.3	0.1	−0.1	1.2	0.1	0.0	0.0	1.0
	OBL	139	0.4	0.1	(276)	(138)	0.3	0.1	(276)	(138)	0.1	0.0	(276)	(138)
S. Carolina 1982 (OE 82-04)			Total fish				Blackbelly rosefish				Tilefish (all species)			
Untransformed	BL	34	16.3	84.3	−1.8	1.4	12.5	57.9	−1.7	1.3	1.9	2.9	−1.6	2.8*
	OBL	34	20.6	122.1	(66)	(33)	15.8	72.8	(66)	(33)	2.8	8.0	(66)	(33)
Transformed	BL	34	1.2	0.1	−1.9	1.3	1.1	0.1	−1.8	1.3	0.4	0.1	−1.0	1.5
	OBL	34	1.3	0.0	(66)	(33)	1.2	0.1	(66)	(33)	0.5	0.1	(66)	(33)

and the total finfish catch for each of the three cruises. Mean catches were significantly different among transformed and untransformed data. Mean numbers of snapper (1983 data) and tilefish caught by bottom and offbottom longlines were not significantly different (Table 3).

Comparisons of means and variances for all untransformed numbers of fish caught by bottom and offbottom longlines indicated that catches of all species groups and total catches were significantly different (Table 3). Catches of two total fish groups (cruises *Oregon II*-129 and *Oregon* OE 82-04) and blackbelly rosefish by the two gear types were not significantly different when transformed values were compared.

Catches were similar between bottom and offbottom longlines when the unit of effort compared was a "set" (not standardized to catch per 100 hooks returned (Table 4)) but offbottom longlines were always fished with at least twice as many hooks over the same general distance as the bottom longline. There were no significant differences in the mean numbers of fish caught by the two gears for any species group during any cruise when tested with either untransformed or transformed data (Table 4).

Hook Loss

Regardless of gear, hook losses were less than 10 percent. Partial hook loss ranged from 0.6 percent of the hooks deployed (offbottom longlines off the Charleston Lumps) to 7.3 percent (bottom longlines in Caribbean). During each cruise, bottom longlines consistently lost more hooks than did offbottom longlines (Table 5).

Discussion

The nearly identical catch composition between bottom and offbottom longlines within similar geographical areas indicates similar behavioral characteristics to the fishing gear when the same bait and hook sizes are fished. Thus the question of efficiency rests with both the CPUE and ease of deployment and retrieval.

Trends in the vertical distribution of catch on offbottom longlines were evident only among nonpriority species.

Table 5.—Hook loss by cruise and gear type.

Gear	Caribbean OII 129 No.	%	Caribbean DII 83-06 No.	%	Charleston OE 82-04 No.	%
Bottom longline						
Total	246	4.5	138	7.3	26	1.2
Partial[1]	196	3.6	138	7.3	26	1.2
Offbottom longline						
Total	654	5.0	277	7.2	29	0.6
Partial[1]	414	3.1	177	4.6	29	0.6

[1]Does not include hooks lost in loss of complete sets.

Catches of priority species were too low for conclusive results which may be an indication of a low population size. Blackbelly rosefish and sharks were caught more frequently at lower hook positions suggesting a high abundance or close association with the bottom. The higher number of grouper and blueline tilefish (*Oregon* 82-04) caught on the upper hooks may indicate a reduced dependency on the bottom or the unavailability of lower hooks due to their utilization by blackbelly rosefish and/or sharks. Species feeding patterns or food preference may also make the lower hooks more attractive.

Significant differences were noted between mean catch rates per 100 hooks of bottom and offbottom longlines (Table 3). This difference is an expression of the higher number of hooks along the bottom on a standard longline and the generally higher catch rate of the lower hooks on offbottom longlines. When comparing catch rates between sets, irrespective of the number of hooks, no significant difference is noted between the two gear types (Table 4). The equality of catch between bottom and offbottom longlines reflects the larger number of hooks fished on offbottom longlines. The similarity in catch and its nonsignificance between gear types when measuring catch per set indicates that a given number of fish in a given habitat will be caught irrespective of the gear type or bait used. Bottom longlines caught more fish per 100 hooks than did offbottom longlines.

Hook loss was an indicator of gear fouling on rough habitats. However, this type habitat is where the highest concentrations of commercially exploitable stocks are found. A larger number of hooks, expressed as percent per set, was lost from bottom longlines as more hooks were in direct contact with the bottom. Although a higher percentage of hooks was lost from bottom longlines, this gear may be a better deep-water reef fish assessment tool as offbottom longlines were more difficult to bait, set, and retrieve. In addition, upon retrieval they were often tangled and difficult to clear with the resultant loss of fishing time and possibly a portion of the catch (Fig. 1). Offbottom longlines were designed to minimize bottom fouling and gear loss on rough bottom habitats, but this advantage was offset by frequent handling difficulties. For population assessment, because of the habitat specificity of the exploitable species, the best gear configuration may be a "short" bottom longline directed at a specific habitat. Retrieving a "short" set straight off the bottom reduces loss of fishing gear by minimizing potential fouling. These conditions influenced SCWMRD to use short habitat specific setlines to investigate deep-water demersal finfish resources off South Carolina and northern Georgia (Low et al., 1983).

Recommendations

Short (30 m) bottom longlines with 20-30 hooks fishing within specific habitats may be a more realistic gear configuration for evaluation of deep-water stocks and their distribution. Insufficient inshore effort has been expended in areas of high relief to evaluate offbottom longlines for inshore populations; however, they may be a useful tool for stock assessment in this habitat. Surveys using offbottom longlines should be conducted from vessels not exceeding 15 m as large vessels tend to pull the mainline to the vessel causing tangles when dragging the mainline and poles across the bottom. Small vessels can more easily maintain position over the mainline allowing the gear to be hauled straight off the bottom.

Acknowledgments

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Observations of Deepwater Shrimp, *Heterocarpus ensifer*, From a Submersible off the Island of Hawaii

REGINALD M. GOODING, JEFFREY J. POLOVINA, and MURRAY D. DAILEY

Introduction

In Hawaii and other Pacific island groups there has been considerable interest in the commercial potential of deepwater caridean shrimps of the genus *Heterocarpus*. Exploratory trapping surveys have shown that deepwater shrimps are widely distributed throughout the central and western Pacific (Clarke, 1972; Struhsaker and Aasted, 1974; Wilder, 1977; Intes, 1978; Brown and King, 1979; King, 1980, 1981a, 1981b, 1982, 1984, 1986; Moffitt, 1983; Gooding, 1984; Dailey and Ralston, 1986; Ralston, 1986; Moffitt and Polovina, 1987).

The Southwest Fisheries Center's (SWFC) Honolulu Laboratory of the National Marine Fisheries Service, has conducted surveys of deepwater shrimp resources in Hawaii (Gooding, 1984) and the Mariana Islands (Ralston, 1986; Moffitt and Polovina, 1987).

Despite the recent economic failure of a large commercial endeavor that was engaged in a trap fishery for *Heterocarpus laevigatus* in Hawaii, (Schlais, 1982, 1983) the deepwater shrimp resource continues to offer promise for commercial exploitation in Hawaii and indeed throughout the southern and western Pacific islands. In the Hawaiian Islands *H. laevigatus*, which occurs most abundantly in depths of 450-700 m and *H. ensifer* which has a shallower preferred depth range of 300-600 m (Clarke, 1972; Struhsaker and Aasted, 1974; Gooding, 1984; Dailey and Ralston, 1986), have been targets of trap fisheries. However, *H. laevigatus* is generally considered to have the greater commercial potential because it is larger.

At present there is no Fishery Management Plan (FMP) for deepwater shrimps. The Western Pacific Regional Fishery Management Council (Council) has identified the *Heterocarpus* resource as one in need of further basic research for effective future management[1]. The Honolulu Laboratory is presently conducting "intensive fishing experiments" on isolated *H. laevigatus* grounds to acquire estimates of absolute and relative abundance of exploitable stocks (Ralston, 1986). For management purposes there is a need for research into population biology and stock assessment, growth rates and natural mortality, and migration patterns. Commercial catch and effort data and research survey data from surface vessels provide much of this information. Visual observations from a research submersible can give a valuable insight into areas such as general behavior and microdistribution relative to types of fishing gear and the nature of the bottom (Ralston et al., 1986). Such direct observations may be very useful in interpreting data acquired by other means and in developing more efficient gear and fishing techniques.

In February 1984, we had the opportunity to use the Hawaii Undersea Research Laboratory (HURL) submersible, *Makalii* (Fig. 1), to make observations of *H. ensifer* off the northeast coast of the Island of Hawaii. The project was confined to *H. ensifer* grounds because the maximum operational depth of the *Makalii* is less than the depth at which *H. laevigatus* occurs. The objectives of the dives were to: 1) Determine factors that might cause variation in *H. ensifer* catch rates within a string of five traps, 2) observe the behavior of shrimp in the vicinity of two different trap designs, 3) document observed distribution and abundance of shrimp relative to type of substrate, 4) set bait on the bottom as an attractant to acquire further insight into shrimp density relative to type of substrate, and 5) collect shrimp specimens, bottom sediment, and water samples for a laboratory assay of incident bacteria. A problem for the shrimp industry that has limited the marketability of *Heterocarpus* spp. has been a rapid deterioration in the meat, so-called "mushy tail." This is believed to be caused by bacteria of the genus *Vibrio*. Four species of the genus had been identified by one of the authors (Dailey) in cultures of shrimp landed from commercial traps. We hoped to determine if these bacteria are either always on the shrimp and cause no problem for the living animal, or are subsequently picked up in the upper water column, or even after the shrimp has been landed on the vessel.

Because the *Makalii* became available

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[1]Western Pacific Regional Fishery Management Council. 1984. Draft assessment of resources, existing and potential fisheries, and management needs for selected crustacean species in the Western Pacific region. Rep. on file at Western Pacific Regional Fishery Management Council, 1164 Bishop Street, Suite 1405, Honolulu, HI 96813.

for the project on very short notice, we were able to fabricate and transport only six shrimp traps to Hawaii from Oahu. Four traps were lost early in the project so we were unable to acquire any information on the catch of similar traps on a string in relation to substrate variations.

Methods

The *Makalii* is a two-man, battery-powered, one-atmosphere submersible owned and operated by HURL, University of Hawaii, and funded by the National Oceanic and Atmospheric Administration (NOAA), National Undersea Research Program (NURP). It is 4.8 m long and has a spherical capsule 1.5 m in diameter. With a pilot and one observer and up to 95 kg payload, it has an operational depth capability of about 366 m and a dive duration of 4-5 hours with emergency life support for 72 hours. Normal operating speeds range from 1 to 3 knots.

During this study, equipment that was used included: Hydraulic manipulator, two-color video cameras with monitors, recorders, and video lights, externally mounted 35 mm still camera and strobe, current and temperature meters, dictaphone tape recorder, directional antenna, and sonic pingers for site relocation. A Motorola Mini-Ranger Falcon[2] navigation system provided very precise (within 15 m) position fixes for the support vessel which tracks the submersible with an Edo Western submersible tracking system. The *Makalii* is also equipped with a Neil Brown environmental monitoring package for continuous recording of temperature, salinity, conductivity, pH, oxygen, and depth.

While on the bottom, observations were continuously video- and voice-recorded and still photographs were frequently made with the 35 mm camera and strobe.

Observations were made on two types of traps. The first was a half-rounded design with an entrance at each end (Fig. 2). This design has been used during past shrimp surveys by the SWFC Honolulu Laboratory (Gooding, 1984). The second trap was a larger pyramid-shaped design with a single entrance at the apex (Fig. 3). This was the preferred trap used in the former Hawaiian commercial fishery (Schlais, 1983). Traps were baited with Pacific mackerel, *Scomber japonicus*, and were set from the submersible support vessel. Attached sonic pingers en-

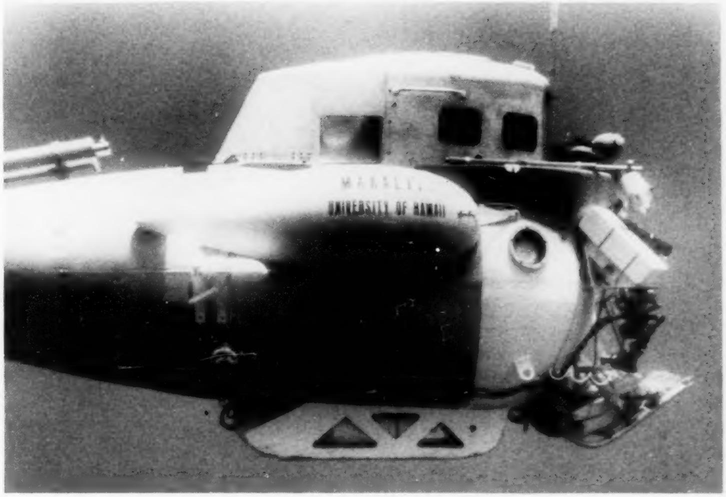

Figure 1.—The NOAA submersible, *Makalii*.

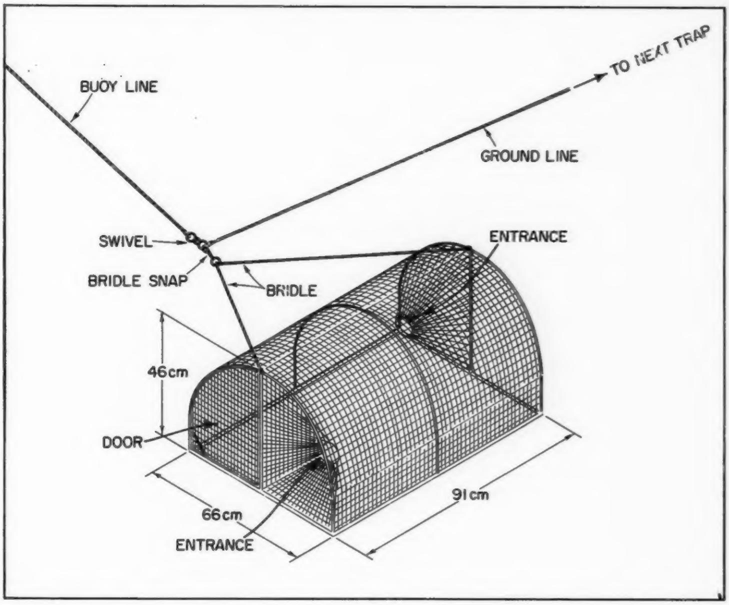

Figure 2.—Half-round shrimp trap.

[2]Mention of trade names or commercial firms does not imply endorsement by the authors or the National Marine Fisheries Service, NOAA.

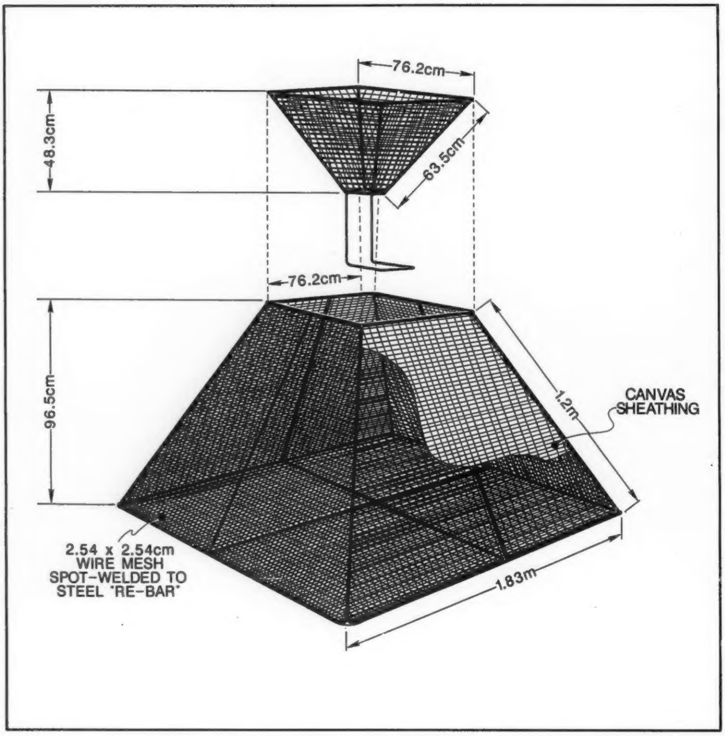

Figure 3.—Pyramid shrimp trap.

abled the submersible to locate them when it reached the bottom. Submersible observations were made on trap sets shortly after setting (1.5-5 hours) or about 24 hours after setting. The traps were retrieved after either 24 or 48 hours on the bottom. After removal from the traps the catches were held in crushed ice until later processing at dockside. Individual shrimps were not weighed. Mean individual weights were derived by dividing total weight of catch by number of shrimp.

The density of shrimp in an area was estimated by monitoring the number of shrimp aggregating to a can of tuna with numerous small punctures on all its surfaces during 10-minute intervals. The cans were sealed in plastic bags and carried in the submersible's sample storage basket. They were placed on the sea floor and the plastic bag torn away with the manipulator.

For the bacteriological tests, individual *H. ensifer* were collected from the bottom with the submersible suction collector. A bottom sediment sample was collected from the area in which shrimp were located and a sample of water close to the bottom was collected in a modified Van Dorn bottle. In the laboratory 0.1 ml of raw inoculant from each of the samples was plated on TCBS to determine total *Vibrio* and on marine agar to determine total bacteria.

The submersible observations were conducted on the Mauna Kea ledge about 12 n.mi. northeast of Hilo harbor. This general area was recommended by Edith Chave of HURL who had seen numerous *H. ensifer* there on an earlier *Makalii* dive.

Results and Discussion

Figure 4 shows the location of the dive sites. Depths ranged from 345 to 380 m, and bottom temperature was 7°-8°C. Within these narrow ranges, temperature and depth were not correlated with either the apparent abundance of *H. ensifer* as observed from the submersible or the size of trap catches. Bottom currents were 0.2-0.3 knot (10-17 cm/second). The dives showed that for the most part the bottom was a flat basalt plain largely consisting of a shallow layer of brownish silty sand overlying volcanic lava flows. Occasionally the nearly flat relief was interspersed with small areas of low lava outcrops covered with limestone cement rising to about 20 cm above the sand. Although there was considerable amount of sediment and apparent turbidity in the upper and midwater column, water clarity at the bottom was very good except when the fine silt was disturbed by the submersible.

Trap Observations

Five dives (*Makalii* dive No. 216-220), totaling 16.75 hours of bottom observation time, were made during 5-13 February 1984. Table 1 summarizes the schedule of dive and trapping operations. Prior to the arrival of the traps from Honolulu, on dive No. 216 we conducted a preliminary survey to determine a suitable area for subsequent trap sets and observational dives. The area surveyed on dive No. 216 consisted almost entirely of silty sand overlying a hard flat substrate. There was a high incidence of *H. ensifer* widely distributed throughout the region traversed by the *Makalii*. Shrimp densities were estimated at up to 1 per m^3 in some areas. Subsequent operations were conducted in the same general vicinity.

During the following four dives (217-220) we made observations on *H. ensifer* in relation to varying combinations of trap configuration, trap soak time, and bottom type.

1) Dive 217. A string of five half-round traps, spaced 16 m apart. All of the traps in the string landed upright in a depth of 347 m. They were clustered closely together on flat rubbly substrate interspersed with low outcrops. During

the observation period the traps had been on the bottom for from 1.5 to 4 hours. Only a few scattered *H. ensifer* were seen in the vicinity of the traps and the largest catch in any one trap appeared to be about four shrimp. A survey in the vicinity of the site showed the traps had landed on contiguously rocky rubbly ground apparently devoid of silty sand substrate in the vicinity. *Heterocarpus ensifer* were not seen on the rocky ground but unidentified striped shrimp were visible in small caves in the substrate. These probably were *Plesionika longirostris* which were subsequently identified on dive 219. During retrieval of the traps the following day, the groundline broke and four of the traps in the string were lost. The recovered trap contained 69 *H. ensifer* (not weighed).

2) Dive 218. A single pyramid trap which landed upright on sandy bottom at a depth of 349 m. No rocky areas were seen in the vicinity. The first observations were made about 24 hours after the trap had been set. The trap contained a large number of *H. ensifer* with many shrimp climbing up the sides, and in the funnel entrance. Many others were on the bottom surrounding the trap. The average size of the shrimp seemed so large that at first the observers thought that despite the relatively shallow depth, some of them were *H. laevigatus*. The trap was hauled the following morning after a soak-time of about 48 hours. It contained 914 *H. ensifer* weighing 16.8 kg with a mean individual weight of 18.4 g. No *H. laevigatus* were found in the catch.

3) Dive 219. A pyramid trap and a half-round trap spaced 15 m apart were deployed together. Both traps landed upright on very fine silty sand overlying a hard substrate. They were about 10 m apart at a depth of 347 m. The traps had been set the previous morning so they had been on the bottom for about 24 hours when observations began. Both traps were filled with shrimp. *Heterocarpus ensifer* were walking over the half-round trap and on the sides of the pyramid trap (Fig. 5). The surrounding sandy bottom was covered with *H. ensifer*. As had been observed during the previous trap set, the average size of the *H. ensifer* was uniformly large with very few small individuals in or around the traps. Shrimp

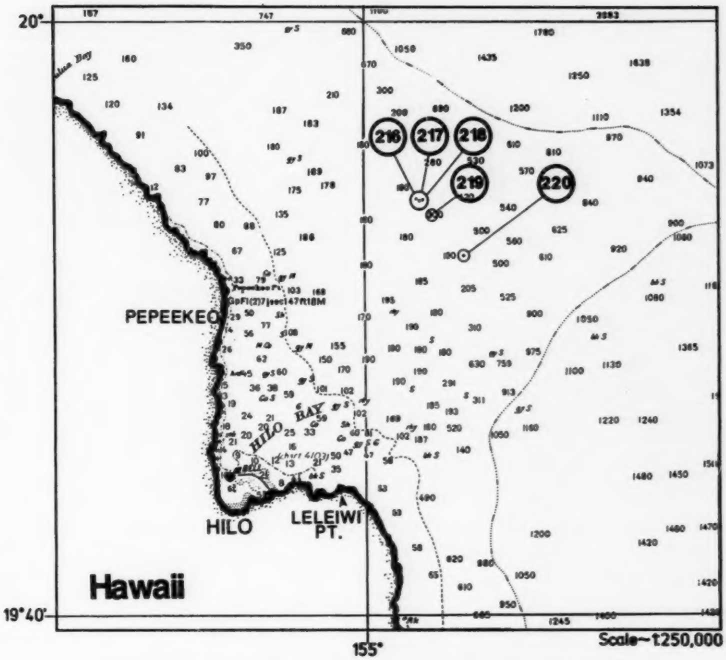

Figure 4.—Dive sites off the Island of Hawaii (soundings are shown in fathoms).

Table 1.—Trapping observations of *Heterocarpus ensifer* during *Makalii* dives off Hawaii.

Observation	Dive number 216	217	218	219	220
Depth of traps (m)	375-385[1]	347	349	347	347
Bottom type	Silty sand over hard substrate	Lava rubble and low outcroppings	Silty sand over hard substrate	Silty sand over hard substrate	Silty sand over hard substrate
Trap soak time when observed (h)	No traps set	1.5-4	24-27	24-27	1.5-4
Trap soak time when hauled (h)		26	48	48	21
Abundance of *H. ensifer* observed in the area	High	Low	High	High	High
Abundance of *H. ensifer* observed in pyramid trap			High	High	High
Abundance of *H ensifer* observed in half-round trap		Very few		High	High
No. of *H. ensifer* landed in pyramid trap			914	1,497	1,676
No. of *H. ensifer* landed in half-round trap		69		1,016	1,110

[1]Range of depths observed during the dive.

Figure 5.—Half-round trap on the bottom in a depth of 347 m; dive 219.

were frequently seen both entering and exiting the half-round trap. When they entered the conical entrance, which on this type of trap was at ground level, they usually climbed in. However, they also were observed swimming in and out. Although shrimp sometimes swam to heights approaching 2 m above the bottom, none was observed swimming into the apical entrance of the pyramid trap. They were observed in various stages of climbing up the sides of the trap towards the entrance, and into the entrance. No shrimp were observed exiting the pyramid trap. A survey of the bottom in the vicinity around the traps showed it consisted mostly of silty sand. The exception to the otherwise flat sandy topography was a small area of lava outcrops about 30 m from the trap site. There solitary striped shrimp, *P. longirostris*, were in holes and cracks in the hard substrate. The traps were hauled the following morning after being in the water for about 48 hours. The pyramid trap caught 1,497 *H. ensifer* weighing 28 kg. The half-round trap caught 1,016 *H. ensifer*, weighing 19 kg, and 7 *P. longirostris*. The mean individual weight of *H. ensifer* taken in each trap was 18.7 g.

4) Dive 220. A pyramid trap and a half-round trap spaced 15 m apart. Both traps landed on typical silty sand ground about 10 m apart in a depth of 347 m. The half-round trap was upright but the pyramid trap was on its side. The *Makalii* reached the traps about 1.5 hours after they had been set earlier that morning. The surrounding area was already covered with *H. ensifer* and shrimp were crawling over both the traps. Despite a soak time of less than 2 hours they both appeared to contain more shrimp than we had thus far seen. As on the previous dive, shrimp were both entering and exiting the half-round trap. Unfortunately, because of the danger of becoming fouled in the groundline, we were unable to get into a position to observe the entrance of the pyramid trap which in its overturned position lay close to the bottom.

During the 2.5-hour period between the first and last observations of the half-round trap there did not seem to be a noticeable increase in *H. ensifer* around or inside the trap. When it was hauled 21 hours later, the catch, although substantial, did not appear to be much different from what we had observed from the submersible. The pyramid trap caught 1,676 *H. ensifer* weighing 32 kg and the half-round trap caught 1,110 *H. ensifer* weighing 21 kg. The mean individual weights of *H. ensifer* were 19.1 g in the pyramid trap and 18.9 g in the half-round trap.

These observations showed that *H. ensifer* are attracted very rapidly to baited traps, and that a large percentage of the animals within olfactory range (depending on current conditions) may enter a trap within 2-3 hours of setting. Both traps with top entrances and those with entrances close to the substrate are efficient in allowing *H. ensifer* to enter. However, if the shrimps are satiated or the bait depleted, they apparently can more easily exit a trap with a horizontally oriented entrance near the bottom than one with a vertical top entrance. Thus small traps with bottom entrances may be more suitable for relatively short soak periods. For instance, an early morning set, and haul before noon. For longer soaks (overnight) a taller trap with a top entrance may hold the catch more efficiently.

King (1981) cited data which suggests that *H. ensifer* and *H. laevigatus* only enter traps during night. In surveys by the SWFC Honolulu Laboratory, good catches of *H. laevigatus* were made during daylight sets[3]. From deepwater photo sequences of baited traps made off Palau, Saunders (1984) found that the upper range of *H. ensifer* appeared to be strongly influenced by daily photic fluctuations. They were abundant in night sequences at 150-250 m depths, but were not recorded in daylight sequences shallower than 274 m. However, at greater depths there appeared to be no differences in either activity or numbers of individuals in day versus night photo sequence. Our trap sets were all well below 274 m. It is also likely that photic penetration is relatively limited off the east coast of Hawaii, which is subjected to considerable natural runoff as well as sugar factory effluent compared with Palauan waters. This study showed conclusively that, during peak daylight hours at the depths observed, *H. ensifer* are active feeders and will readily enter traps.

[3]Honolulu Laboratory, Southwest Fisheries Center, 2570 Dole St., Honolulu, HI 96822-2396. Unpubl. data.

However, we are not aware of any investigation which has rigorously compared the relative merits of day and night trapping for *Heterocarpus* spp. The shrimp catches in both trap types were *H. ensifer* with the exception of the seven *P. longirostris* caught in the half-round trap observed on dive 219. No *H. laevigatus* were found in any of the catches.

We were impressed by the uniformly large size of *H. ensifer* viewed from the submersible and caught in the traps. The mean individual weights of *H. ensifer* from the two types of traps were virtually identical, at about 18.8 g. This was quite large when compared with a mean weight of 12 g for *H. ensifer* taken during trapping surveys in the NWHI (Gooding, 1984), and a maximum weight for *H. ensifer* of about 16 g reported by Struhsaker and Aasted (1974). Some studies have indicated that large *H. ensifer* occur within the depth range of maximum abundance, with smaller animals occurring both shallower and deeper (Clarke, 1972; Struhsaker and Aasted, 1974; King, 1981a). However, Moffitt and Polovina (1987) found no significant change in the size of *H. ensifer* with depth. Our observations were made at the shallow end of the range of maximum abundance for *H. ensifer* found by Gooding (1984). The submersible surveys revealed virtually no small individuals in the vicinity of the traps or the surrounding area. Thus we speculate that smaller size classes were occupying other habitats. The shrimp were not methodically sexed but inspections of the catches showed the presence of both sexes with a high incidence of berried females.

On *H. laevigatus* surveys in the Mariana Islands, Ralston (1986) found that pyramid traps outperformed half-round traps by a ratio of nearly 6:1. In this study, for the two sets (dive 219 and 220), when pyramid and half-round traps lay adjacent to one another on the same type of ground, the pyramid traps caught only 1.5 times (60 kg) the catch of the half-round traps (40 kg).

On dive 220 the pyramid trap that was lying on its side fished equally well relative to the attached half-round trap as did the upright pyramid observed on dive 219.

Figure 6.—*Heterocarpus ensifer* aggregated around tuna can in a depth of 347 m; dive 220.

Table 2.—Rate of *Heterocarpus ensifer* aggregation to a punctured tuna can as the number of animals observed over a 10-minute period.

Elapsed time (min.)	Rocky outcropped bottom			Sandy rubble bottom	Silty sand bottom		
	Dive 219 Test 1	Dive 219 Test 2	Dive 220 Test 1	Dive 219 Test 3	Dive 219 Test 4	Dive 220 Test 2	Dive 220 Test 3
1	1	0	0	1	2	2	7
2	1	0	0	1	5	8	14
3	1	0	0	1	9	13	20+
4	1	0	0	1	12	20	30+
5	1	0	0	2	20+	30+	
6	1	1	0	2	30+		
7	1	1	0	2			
8	1	1	0	2			
9	1	1	0	2			
10	1	1	0	2			

Tuna Can Observations

Punctured tuna cans (Fig. 6) were deployed on three substrate types: Silty sand, rocky outcroppings, and sandy rubble. Table 2 lists the number of *H. ensifer* which aggregated to the bait in each test during 10 minutes of observation. The *H. ensifer* were apparently following the odor gradient and invariably approached the can from the down-current direction. On one rocky ground test the can was placed about 2 m directly up-current of an outcropping in which we could see several *P. longirostris*; however, none of them left their holes to approach the can. On the sandy ground there was initially a rapid increase in the aggregation rate of *H. ensifer* with time which appeared to start leveling off after about 7-8 minutes. We were unable to make counts beyond about 30 animals. These crude tests clearly indicate a much higher density of *H. ensifer* on the sandy silt substrate than on the two others.

Other Behavior

Heterocarpus ensifer apparently were neither attracted, repelled, nor affected in any way by the lights from the sub-

mersible. When, after a period of total darkness, the flood lights were turned on to large aggregations of *H. ensifer* gathered around traps, we were unable to discern any changes in their behavior. On dive 220 we had the opportunity for just a few seconds to observe *H. ensifer* in something approaching an undisturbed natural state. As the *Makalii*, following its descent from the surface, approached to within about 3 m of the flat sandy bottom, we were able to see *H. ensifer* all over the sandy surface out to the limits of visibility. They were solitarily distributed, about 1 per m^2. As the submersible settled on the bottom, some of the shrimp which were within about 1-2 m from the *Makalii* swam vertically to as high as about 2 m from the bottom. More distant shrimps, although suddenly subjected to greatly increased light, remained undisturbed. Our impression was that the disturbed *H. ensifer* were reacting to the sudden physical presence of the submersible in their midst rather than to the light.

We did not see any burrowing in the sand by *H. ensifer* on this occasion or during other observations. This supports aquaria observations which indicated that *Heterocarpus* sp. did not burrow in the substrate (King, 1986).

It is well known from the condition of shrimp in trap catches that *Heterocarpus* are cannibalistic. We did not usually observe any overt aggressive behavior amongst shrimp under the various conditions of our study. However, in two instances it was shown vividly that an *H. ensifer* that finds itself at a disadvantage to its fellows quickly becomes fair game. When the tails of animals within a trap protruded through the mesh, shrimp on the outside would start feeding on the tail, and on one occasion during observations of shrimp attracted to a tuna can, an *H. ensifer* which was injured by the submersible's manipulating arm was immediately attacked by other shrimp in the area.

Bottom Habitat

Our observations from the *Makalii*, the subsequent trap catches, and the tuna can aggregation tests showed that of the two distinct types of substrate we encountered on Mauna Kea ledge, i.e., low profile outcropping and silty sand overlying flat substrate, the preferred type of ground for *H. ensifer* was clearly the latter. Of the six traps we recovered, the two half-round traps that landed on flat sand had a mean catch rate of 20 kg per trap whereas the half-round trap observed on rocky ground caught only 69 *H. ensifer* (probably about 1.2 kg). The three pyramid traps, all of which were on sand, had a mean catch rate of 25.6 kg per trap. Conversely, with the exception of a single *P. longirostris* observed on the bottom in front of the half-round trap on dive 219, we did not see any other of this species on sandy ground. Seven *P. longirostris* were caught in the trap which was lying about 30 m from an area of exposed hard substrate on which *P. longirostris* were seen under ledges and in small holes. No *P. longirostris* were caught in the pyramid trap on the same string. However, the half-round trap on dive 217 that lay on rocky ground where we had seen *P. longirostris*, did not catch any *P. longirostris*. Unfortunately, the other four traps on the same string were lost.

Bacterial Tests

The results of the bacteriological culture assays (Table 3) indicate that *Vibrio alginolyticus* and another *Vibrio* sp. found commonly in and on both *H. ensifer* and *H. laevigatus* are apparently not acquired in the trap during hauling or after the shrimp are landed on the vessel.

Table 3.—Results of bacteriological tests to determine the distribution of *Vibrio* sp.

Item	TCBS	Marine agar
Shrimp	4+ *Vibrio alginolyticus* and one other *Vibrio* sp. (not identified)	4+
Bottom sediment	2+ One *Vibrio* sp. found. The same as the unidentified species from the shrimp	4+
Water column	0 No *Vibrio* sp. recovered.	4+

1+ = 100 colonies/ml.
2+ = 100-500 colonies/ml.
3+ = 500-2,000 colonies/ml.
4+ = 2,000 colonies/ml.

The indication of a 4+ growth on the *H. ensifer* compared with a 2+ growth in the surrounding bottom material implies that the shrimp are likely a primary substrate for the *Vibrio*. A 4+ on the marine agar indicates other bacteria, primarily *Pseudomonas* spp. are ubiquitous on the bottom as well as in the water column.

Vibrio alginolyticus, *V. parahaemolyticus*, and *Vibrio* sp. have also been found commonly on marine mammals inhabiting the upper water column (Dailey, 1985). This would tend to verify that animals rather than the water column or bottom serve as the primary substrate for these microorganisms.

Conclusions

Because of various logistic factors the observations and tests conducted during these dives were somewhat limited in scope and sophistication. Nevertheless, the results show that valuable insights into trap siting and trap design relative to deepwater shrimp ecology and behavior and also more general aspects of the biology of shrimp can be acquired using a research submersible. This type of information can complement and supplement data collected by more conventional methods.

The HURL has recently acquired the *Pisces V*, a three-man, one-atmosphere submersible that can reach depths of 2,000 m. Planned SWFC Honolulu Laboratory studies on *H. laevigatus* from the *Pisces V* will provide information about this potentially more valuable species which, we hope, will contribute to the development and management of deepwater shrimp fisheries in Hawaii and other Pacific island areas.

Acknowledgment

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Toward Developing an Inventory of U.S. Coastal Wetlands

DON W. FIELD, CHARLES E. ALEXANDER, and MARLENE BROUTMAN

Introduction

Despite a growing awareness of the importance of coastal wetlands, there is no data base to document their current distribution and abundance. Existing coastal wetlands inventories have been conducted for the most part at state and local levels, and they lack a unified system of classification and quantification. Recognizing this gap in wetlands information, the National Marine Fisheries Service (NMFS) and the Strategic Assessment Branch (SAB) (Ocean Assessments Division, Office of Oceanography and Marine Assessment, National Ocean Service) undertook a cooperative effort to compile existing coastal wetlands information by individual coastal county for the 22 coastal states in the contiguous United States, excluding the Great Lakes.

Development of this information is an integral part of NOAA's strategic assessments of the nation's coastal and oceanic regions (Ehler and Basta, 1984) and it's national program to determine the status and trends of coastal fisheries habitat (Lindall and Thayer, 1982; Thayer et al., 1985). The initial objectives were to: 1) Compile available coastal wetlands information by county and state, 2) evaluate their adequacy for strategic planning and assessment, and 3) provide an initial data base on wetlands for the assessment of available fisheries habitat. Plans for further use of the information and its improvement are also discussed.

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What Is a Wetland?

Wetlands are typically transitional areas between terrestrial and aquatic systems where the water table is at or near the surface or the land is covered by <6 feet of water (Cowardin et al., 1979; Frayer et al., 1983). Many different types of wetlands occur in a wide variety of settings. These include salt marshes along the ocean coastline, bottomland hardwood forests in the southern states, and prairie potholes in the midwest.

Because the reasons for defining wetlands are as diverse as the wetlands themselves, there is no single, indisputable definition for wetlands. To identify and delineate wetlands accurately for resource management, the U.S. Fish and Wildlife Service (FWS) developed a detailed classification system in 1979 that broadly defines wetlands as follows: ". . .wetlands must have one or more of the following three attributes: 1) at least periodically, the land supports predominantly hydrophytes; 2) the substrate is predominantly undrained hydric soil; and 3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season each year" (Cowardin et al., 1979).

The definition, and the classification system, are based on 5 years of field testing and review. Both are now widely accepted as national and international standards for wetlands management (Tiner, 1985). Even so, they do not suit the needs of all wetlands investigators. For example, a more restrictive definition has been developed by the U.S. Environmental Protection Agency (EPA) and the U.S. Army Corps of Engineers (COE) for regulatory purposes. In this case, wetlands are defined as: ". . .those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas" (Fed. Regist., 19 July 1977; 22 July 1982). As a result, EPA and the COE estimate their regulatory jurisdiction extends to over 64 million wetland acres in the contiguous United States (OTA, 1984). In contrast, the FWS reports the presence of 99 million acres of freshwater and estuarine wetlands for this same area based on the Cowardin system.

Differences in how wetlands are defined have caused considerable controversy and debate. This problem is compounded when compiling a comprehensive national data base because regional and state wetland inventories, representing much of the available data, have often used different definitions and inventory techniques to describe wetland boundaries.

Why Is This Data Base Needed?

Coastal wetlands are an important national resource. From Maine to Florida, across the Gulf of Mexico to Texas, and intermittently along the West Coast, a thin belt of wetlands provides critical habitat for fish, shellfish, and wildlife (Shaw and Fredine, 1956; McHugh, 1966; Turner, 1977; Flake, 1979; Lindall and Thayer, 1982; Sather and Smith, 1984). They filter and process agricultural and industrial waste (Kadlec and Kadlec, 1979; Tchobanoglous and Culp, 1980; Benner et al., 1982) and buffer coastal areas against storm and wave

damage (Knutson and Selig, 1982). They also are key factors in generating large revenues from a wide variety of recreational activities such as fishing and hunting (NMFS, 1981; FWS, 1982).

However, wetlands are rapidly disappearing in many areas. Urbanization, agriculture, hydrocarbon exploration, and other activities have contributed to the loss of more than 11 million acres of wetlands over the past 25 years (Frayer et al., 1983). Although most of these losses have occurred in inland areas, coastal wetlands have reportedly been depleted at an average rate of about 20,000 acres (31 square miles) per year during this period. Studies indicate, however, that the recent loss rate may be much higher. For example, in coastal Louisiana, Gagliano et al. (1981) estimated wetland losses of nearly 25,000 acres (40 square miles) per year. Furthermore, the U.S. Census Bureau predicts that by 1990, 75 percent of the U.S. population will live within 50 miles of the coastline (including the Great Lakes), indicating even greater competition in coastal areas for limited space and resources in the near future (CEQ, 1984). Despite these facts, no comprehensive information base on the nation's coastal wetlands is available. Therefore, we are really not in a position to judge accurately the current acreage, characteristics, and rate of loss (or gain) of the nation's coastal wetlands resource base.

Data Sources

Information on the extent of coastal wetlands has been developed by a variety of sources including Federal and state governmental agencies, and public and private research organizations.

Federal Data

The National Wetlands Inventory program (NWI) of the FWS and the Land Use and Land Cover program (LU/LC) of the U.S. Geological Survey (USGS) are Federal programs that compile wetlands data at the national level. NWI data, classified according to Cowardin et al. (1979), are used as a source of wetland information for four states (Table 1). LU/LC data were not used because of problems noted below.

The NWI program was established by the FWS in 1974 to generate scientific information on the characteristics and extent of the nation's wetlands and to provide data for making quick and accurate resource decisions (Tiner, 1984). This information was to be developed in two stages: 1) The creation of detailed wetland maps and 2) research on historical status and trends. The maps, developed using aerial photography, generally are based on 1:24,000 scale USGS quadrangles and illustrate wetland habitats based on the Cowardin et al. (1979) wetland classification system. Most of the imagery used to develop these wetland maps was taken in the middle to late 1970's. However, in some areas where more recent photography was not available, imagery as old as 1972 had to be used. While maps have been completed for most coastal areas, only a fraction have been digitized. Therefore, very little actual wetlands acreage data are presently available. Since the quantification of mapped data necessary to successfully capture detailed wetland information is expensive and time consuming, a complete data base of NWI coastal maps is not anticipated in the near future.

A 1983 FWS report on national wetlands status and trends (Frayer et al., 1983) represents the only recent attempt to survey the U.S. coastal and noncoastal wetlands. However, Frayer et al. (1983) suggest that, because data for the report were compiled by random sampling rather than a comprehensive inventory, they are meaningful only at a national or regional level and are generally unreliable for smaller areas such as states, counties, or estuaries.

The LU/LC program at USGS compiles land-use data, including wetlands, based on aerial photography. Although it represents a complete national data base describing nine categories and 37 subcategories of land use and land cover aggregated by state, county, or even hydrologic unit, the wetlands component lacks the detail and accuracy required for strategic assessments. For example, the data base divides wetlands into only two categories, forested and nonforested, with no designation for salt marsh, fresh marsh, or tidal flats. There is also some question about the ability of the LU/LC program to distinguish accurately between forested uplands and forested wetlands. But, although LU/LC data are not the best available for this project, they remain a powerful tool for many other land-use planning and characterization applications.

State Data

Twenty-one of the 22 coastal states in the contiguous United States that were contacted and surveyed had completed some type of wetland inventory; New Hampshire used soil survey data to estimate the acreage of salt marsh. These inventories had generally been conducted by state natural resource agencies and often included estimates of inland, as well as coastal, wetlands. The level of detail, the date the inventories were conducted, and methodology all showed considerable variation among states. The information presented in this report relies heavily on these state level wetland inventories. Table 1 summarizes the salient characteristics of these state inventories.

Compiling Existing State Data

Federal, state, and local agencies, and educational research organizations were contacted by a three-member project team to locate and evaluate available coastal wetlands data for each of the 22 coastal states (Fig. 1). The project team reviewed the acreage estimates, maps, and descriptive materials for appropriate information and, when necessary, made follow-up inquiries by telephone. The review focused in particular on when, how, and why each inventory was conducted. According to vegetative associations described in various inventory materials, the team consolidated wetland acreage data under the general categories of: 1) Salt marsh, 2) fresh marsh, 3) tidal flats, and 4) swamp. For instance, any wetlands identified as including *Spartina* sp. marshes were classified as salt marsh since they represent typical salt-tolerant coastal wetland vegetation. The data were then summarized by county, state, and region. Four wetland categories do not provide a sufficient level of detail for

Table 1.—Time period, methods of determining acreage, wetlands classification system, and references for the reports covering the 22 coastal states.

		Methodology[1]								
State	Time period	Aerial photos	Ground survey	Wetland maps	Planimetry	Dot/grid	Digital	Cowardin	Other system	References
Maine	1975-76	●	●		●				●	McCall, 1972; Maine Dep. Inland Fisheries, Augusta, ME (Unpubl. data); Maine State Planning, Augusta, ME (Unpubl. data).
New Hampshire	1970-74		●						●	Breeding et al. (1974); U.S. Soil Conservation Service, Durham, NH.
Massachusetts	1971-72 1977	●	●	●	●	●	●	●	●	Hankin et al. (1985); MacConnel (1975).
Connecticut	1968	●		●	●				●	Conn. Coastal Area Management Program, Hartford, CT (Unpubl. data).
Rhode Island	1970	●	●	●			●	●		FWS (1984c).
New York	1974	●	?	●	●				●	NYDEC (1974); N.Y. Dep. Environ. Conserv., Stony Brook, NY (Unpubl. data).
Pennsylvania	1970, 1972	●	●	●	?				●	Walton and Patrick (1973).
New Jersey	1976-77	●	●	●			●	●		Tiner (1985).
Delaware	1981-82	●	●	●			●	●		FWS (1984a).
Maryland	1976-77	●	●	●			●	●		McCormick and Somes (1982).
Virginia	Varied 1973-81	●			●				●	Series of tidal marsh inventories prepared by VIMS (i.e., Barnard, Doumlele, Harris, Moore, Priest, Silberhorn citations).
North Carolina	1954	●	●	●					+	Wilson (1962).
South Carolina	1971-77	●	●	●	●			●		Tiner (1977).
Georgia	1975-76	●	●			●			+	U.S. Soil Conservation Service, Athens, GA (Unpubl. data).
Florida	1972-76	●	●		●				●	Florida Dep. Environmental Regulation (1978).
Alabama	1979 & 1979-80	●	●	●	●				●	Stout and Long (1981); Stout et al. (1982).
Louisiana	1976-78	●	●	●	●			●		Wicker (1980).
	1969-75	●	●	●		●			●	Gosselink et al. (1979).
Texas	1950-54	●	●			●			●	Brown (1972-80); Keer et al. (1977).
California	Various dates, 1960's-1980's	?							●	Dennis and Marcus (1984).
Oregon	1972-73	?								Atkins (1973); Oregon Dep. Land Conservation and Development, Salem OR; Oregon Dep. of Fish and Wildlife, Salem, OR.
Washington	Various dates, 1975-82	?						●		Boule et al. (1983).

[1]Symbols: ? Methodology uncertain.
●Methodology as indicated.
+Wetland classification system based on FWS Circular 39 (Shaw and Fredine, 1956).

national and regional analysis of the most important coastal wetland habitats. However, with the variable wetland classification procedures used in the state inventories, a more refined breakdown of wetland types was not possible. Data on submergent wetlands (seagrasses) have been omitted. Submergent wetlands are major resources for fishery organisms as well as birds (Thayer et al., 1984) and should be included in any coastal wetlands data base. Unfortunately, most inventories used in this paper did not cover submergent wetlands.

Twenty-three different sources of coastal wetland data were consulted to compile acreage estimates for the 22 coastal states. Nineteen were independent inventories, compiled by individual states or state-affiliated research organizations. Data were compiled for 242 counties (Fig. 1). For some counties data were unavailable, while for others wetland areas were too few to consider.

Assessing the Estimates

The data compiled indicate the presence of over 11 million acres of wetlands along the Atlantic, Gulf of Mexico, and Pacific coastlines of the coterminous United States. This includes 4.4 million acres of salt marsh, 1.5 million acres of fresh marsh, 211,000 acres of tidal flats, and 5 million acres of swamp. The Gulf of Mexico has the most wetlands (5,184,000 acres) followed by the south-

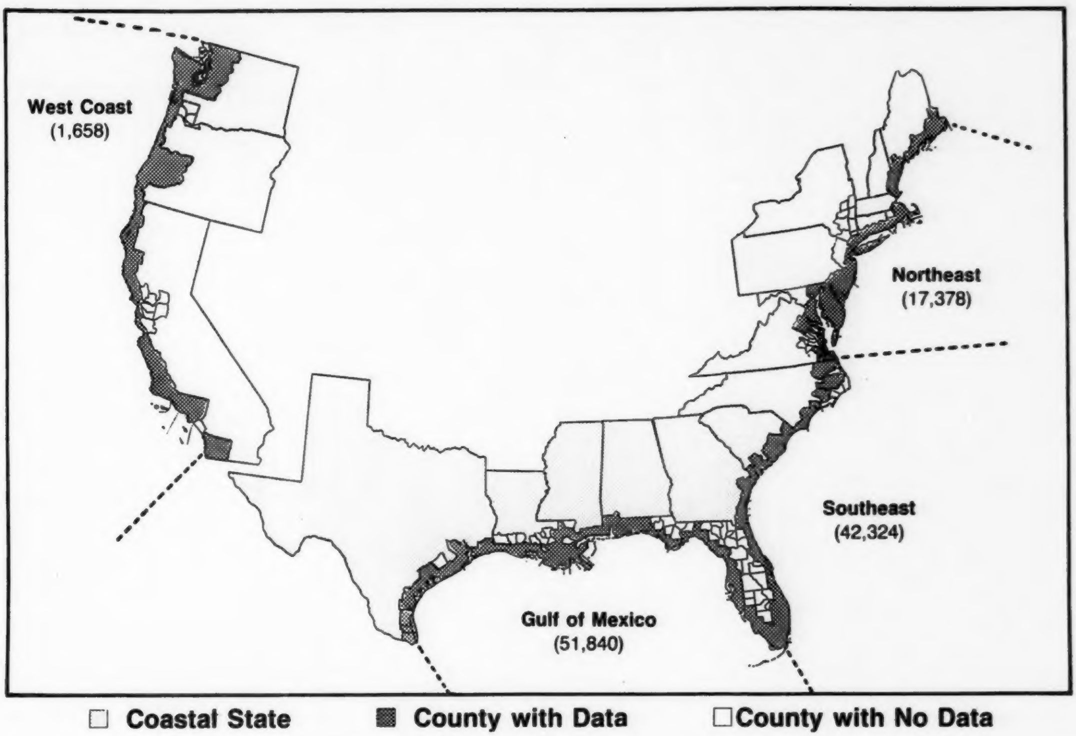

Figure 1.—U.S. coastal regions and wetlands totals (acres × 100).

east (4,232,400 acres), the northeast (1,737,800 acres), and the west coast (165,800 acres) (Fig. 1). Salt marsh and fresh marsh occurred most frequently in the Gulf of Mexico (2,648,900 acres and 859,600 acres, respectively). Swamp areas were most abundant in the southeast (2,652,500 acres), while tidal flats occurred most often in the northeast (161,500 acres).

Table 2 summarizes these estimates by state. More than 60 percent of the wetlands inventoried are concentrated in North Carolina, Florida, and Louisiana while the entire west coast (California, Oregon, and Washington combined) has less than 2 percent. About 40 percent of the coastal wetlands measured have been designated as salt marsh, 14 percent as fresh marsh, 2 percent as tidal flats, and 45 percent as swamp. Lacustrine wetlands, or wetlands associated with lakes and ponds, were excluded where possible, because they are typically inland and not influenced by coastal processes. While this is also true for some swamp areas, noncoastal swamps could not be discriminated from coastal swamps. Salt marsh inventoried for this project totaled 4,446,000 acres compared to the FWS estimate of 3,900,000 acres (Frayer et al., 1983). Other comparisons with FWS data cannot be made since most FWS estimates at the national or regional level include coastal and noncoastal wetlands.

Most of the data originally were developed using aerial photography combined with some ground-truth surveys. Typically, once wetlands were located on maps or photographs, their extent was quantified using either planimetric, dot/grid sampling, or digital techniques (Table 1). For more detailed information on how the wetland types were aggregated see Alexander et al. (1986).

Despite generally good geographic coverage of the data presented, it is impossible to consolidate them into a national data base. Considerable variation exists in wetland definitions and classification schemes. While some states adopted the FWS system (Cowardin et al., 1979), others, in response to their own local or regional needs, developed independent classification systems based on slightly different criteria and boundary conditions. In some cases wetlands were classified into many distinct types, while in others wetland types have been consolidated into broad categories that cannot be disaggregated. Many state inventories were completed prior to 1979 and before the availability of a widely accepted national standard.

In addition, the time period when the

Table 2.—Coastal wetlands data by state.

Region and State	Wetlands acres (X 100) Salt marsh	Fresh marsh	Tidal flats	Swamp	Total	Percent of total
Northeast						
Maine	166	257	583	250	1,256	(1.1)
New Hampshire	75	N/A	N/A	N/A	75	(0.1)
Massachusetts	481	151	415	249	1,296	(1.1)
Rhode Island	79	0	0	571	650	(0.6)
Connecticut	166	N/A	N/A	N/A	166	(0.1)
New York	267	34	N/A	N/A	301	(0.3)
Pennsylvania	0	8	0	0	8	(<0.1)
New Jersey	2,174	217	486	4,723	7,600	(6.7)
Delaware	781	71	113	1,234	2,199	(1.9)
Maryland	1,636	256	18	194	2,104	(1.9)
Virginia	1,523	200	N/A	N/A	1,723	(1.5)
Subtotal	7,348	1,194	1,615	7,221	17,378	(15.3)
Southeast						
North Carolina	1,588	920	N/A	21,075	23,583	(20.8)
South Carolina	3,695	645	N/A	N/A	4,340	(3.8)
Georgia	3,743	315	95	2,860	7,013	(6.2)
Florida (Atlantic)	959	3,834	N/A	2,590	7,383	(6.5)
Subtotal	9,985	5,714	95	26,525	42,319	(37.3)
Gulf of Mexico						
Florida (Gulf)	4,313	755	N/A	9,707	14,775	(13.1)
Alabama	146	106	N/A	1,513	1,765	(1.6)
Mississippi	640	40	N/A	760	1,440	(1.3)
Louisiana	17,486	6,888	N/A	4,372	28,746	(25.4)
Texas	3,904	787	N/A	403	5,094	(4.5)
Subtotal	26,489	8,596	0	16,755	51,820	(45.9)
West						
California	216	44	134	34	428	(0.4)
Oregon	188	63	252	N/A	503	(0.4)
Washington	237	176	22	292	727	(0.6)
Subtotal	641	283	408	326	1,658	(1.4)
Grand total	44,463	15,787	2,118	50,820	113,175	(100.0)
(% of Total)	(39)	(14)	(2)	(45)	(100)	

Table 3.—Comparison of grid sampled and digital data for 16 1:24,000 NWI maps in coastal Louisiana and Texas.

Habitat	Acres Digital	Grid	Percent difference
Upland	109,227	108,495	−0.7
Open water	434,896	433,823	−0.2
Salt marsh	97,642	97,611	<0.1
Fresh marsh	17,584	17,885	+1.7
Tidal flat	8,013	7,861	−1.9
Swamp	1,225	1,016	−13.4
Total	668,587	664,420	−0.6

data were collected for each inventory varied. For example, the last statewide inventory of coastal wetland acreage in North Carolina was 1954, while for Delaware data are based on an inventory conducted in 1980-81. Since coastal wetlands have been subjected over the years to both environmental and developmental pressures, data collected at widely disparate times are often difficult to interpret. Some state inventories are based on detailed and comprehensive inventories, using state-of-the-art technology, while others have relied on incomplete data compiled from scattered projects in various locations.

Consequently, the state, regional, and national data summaries for wetland acreage and distribution compiled for this report, while not necessarily precise, represent order-of-magnitude estimates that can be useful as general indicators of coastal wetlands abundance. Much work remains to be done to develop a comprehensive nationwide assessment capability. Variability in the data quality and consistency of data between states, and lack of a unifying theme or purpose among states, makes the production of an accurate national picture of coastal wetland status and trends difficult.

Ongoing Efforts

Since the existing data proved unsatisfactory for compiling a national data base, a search was undertaken for a cost effective method to quantify the current extent of coastal wetlands. Initial results indicated that using a grid sampling technique on NWI maps offered a reasonable alternative. To test this procedure, a grid sampling technique was used to quantify habitat types for 16 previously digitized 1:24,000 scale NWI maps. For the purposes of these preliminary tests, the numerous habitat types designated on the NWI maps were aggregated into six general categories: 1) Salt marsh, 2) fresh marsh, 3) tidal flats, 4) swamp, 5) open water, and 6) uplands. After some testing, a 45-acre grid cell size with about 900 sampling points per map was determined to be both efficient and accurate for estimating these six habitat types at this scale. Each map was sampled separately by mounting the grid over the map and systematically recording the habitat type at each sampling point. The information was recorded on data sheets and entered into a computer mapping and statistics program. Based on the results (Table 3), it appeared that grid sampling could provide a time and cost effective technique for compiling a reasonably accurate coastal wetlands data base.

Before establishing a full scale grid sampling effort, SAB and NMFS organized a workshop bringing together individuals with experience in wetlands mapping and management to discuss NOAA's efforts to compile a national coastal wetlands data base. Sixteen professionals from six Federal organizations participated. Specific objectives of the workshop were to review current information on the distribution and extent of coastal wetlands and to solicit comments and recommendations from the workshop participants on NOAA's proposed grid sampling project. In, general, workshop participants supported NOAA's proposal to grid sample NWI maps (Strategic Assessment Branch, 1986). Workshop participants recommended, however, that the number of habitat categories sampled

be expanded from six to the fifteen listed below:

1) High salt marsh
2) Low salt marsh
3) Brackish marsh
4) Nonfresh marsh (unspecified)
5) Tidal fresh marsh
6) Nontidal fresh marsh
7) Fresh marsh (unspecified)
8) Tidal flats
9) Estuarine forested-scrub/shrub
10) Tidal fresh forested-scrub/shrub
11) Nontidal fresh forested-scrub/shrub
12) Fresh forested-scrub/shrub (unspecified)
13) Upland
14) Open water-fresh
15) Open water-nonfresh

These categories were incorporated into the operational phase of the project and grid sampling was begun in June 1986. The program is expected to be completed in 1988.

Both NMFS and NOS have identified the status and trends of coastal wetlands as a priority research problem. Reliable baseline data on the current extent of coastal wetlands are needed not only to accurately monitor trends, but to implement appropriate management strategies and assess their impact. Without such data, a coordinated effort to manage coastal wetlands and their associated resources will be difficult to achieve. Data generated by the efforts outlined in this paper should be an important step to a better understanding of our coastal wetland resources.

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A Synthesis of Cost and Revenue Surveys for Gulf of Mexico Shrimp Vessels

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Introduction

The change in operating costs relative to revenues creates an economic incentive for fishermen to alter their levels of fishing effort. The cumulative effect of individual fishermen responding to fluctuating market conditions is a change in both the number and the fishing power of vessels in the fleet. Monitoring the impacts on fleet size of long-run trends in relative costs has been difficult because comprehensive time series cost data are not routinely collected for vessels operating in any of the U.S. southeast region fisheries.

In the case of the shrimp fishery, a number of cost and revenue survey studies have been conducted under the auspices of the National Marine Fisheries Service (NMFS), Sea Grant, and other public and private institutions and organizations. Since these studies were designed to meet specific short-term objectives, their results are not directly comparable because of differences between the surveys. Information from the individual studies can be incorporated in a generalized least squares regression technique to estimate comparable cost and revenue trends, relative costs, and the financial performance of fishing firms operating in the Gulf of Mexico shrimp fishery during the period 1971 to 1980.

Review of Published Cost and Revenue Data

Differences underlying the cost and revenue surveys prevent direct comparisons of their results. Each report surveyed a particular and, in some cases, distinct subset of vessels in the shrimp fleet, resulting in different sample variances. The magnitude of these differences can be seen in the range of the reported means, variances, standard deviations, and other descriptive statistics. For example, mean total revenue for surveyed vessels was reported as $60,142 (Warren and Griffin, 1978) and $9,214 (Duffy and Johnson, 1979). In addition, the sample sizes of the surveys ranged from 1 (Anonymous, 1977) to 115 vessels (Griffin et al., 1976). Vessel characteristics also varied between reports. Vessel length ranged from <24 feet (Duffy and Johnson, 1979) to >70 feet (Griffin et al., 1974). Vessels operated out of Texas (Swartz and Adams, 1979), Louisiana (Roberts and Sass, 1979), and Florida (Blomo and Griffin, 1978). The surveys concentrated on different areas of operation (inshore fisheries vs. offshore fisheries) and were generally restricted to a single year.

Another cause of variation in the reports is the exclusion of information on vessel ownership. The cost structure of a single vessel, owner-operated firm could conceivably be different from the cost structures of vertically integrated, horizontally integrated, or nonowner operated firms. The single vessel, owner-operated fishing firms may maximize the income of a fisherman while the vertically integrated fishing firm may operate at a loss to ensure a continuous supply of fish to the parent company or to maximize profits at some other level within the firm. The reports also did not provide information on the quantity of factor inputs used in the production process such as gallons of fuel or trawl size, and the survey results were reported in current rather than constant or real dollars.

As a result, comparisons of these studies do not provide any information on long-term trends in costs relative to revenues in the shrimp fishery. As an example, consider the comparison of 66-72 foot vessels operating off the coast of Texas (Griffin, et al., 1974) with vessels 24 feet or less in length operating in the bays and rivers of Louisiana (Duffy and Johnson, 1977). Although both studies reported costs and revenues for shrimp vessels, meaningful conclusions cannot be drawn about the long-term trends in the fishery because no common denominator exists between the two reports.

Cost and revenue trends, however, are contained implicitly in the survey data. For example, changes in the cost and revenue structure of the firm from the utlization of a new production technology would have been implicitly represented in the published survey results for that point in time. If these changes are assumed to affect the cost and revenue structures of all firms similarly, then these trends can be used as the common denominator to estimate costs and revenues based on historical data, to interpolate missing values, and extrapolate future values. The differences in the sample variances of each study can be accounted for in a weighted least squares regression analysis (Draper and Smith, 1981:108-109). A set of equations can be estimated from the combined survey results weighted by the sample size of the study. Since weighted least squares corrects for the unequal variances of the observations

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Table 1.—Estimated trend line equations[1].

Dependent variables	Constant	LYR	FA	FB	DG	DL	D	D1	LTP	TD	SD	IOS	F. Stat	r-squared
Total													1178.25	
Revenue	−38.8981	11.2953		−0.4728	0.1472	−0.2853	1.1702	−1.7238	0.261	−0.1861	0.3026	−0.272		
LTR		(9.609)		(9.67)	(4.85)	(6.89)	(34.90)	(36.90)	(5.40)	(2.64)	(3.79)	(7.01)		0.915
Effort													1156.18	
Expense	−0.1354	2.1833		0.1754	0.2218		1.1351	−1.4509		−0.199		0.0996		
LEE		(5.34)		(8.17)	(8.31)		(43.90)	(29.28)		(8.25)		(3.67)		0.881
Total													1689.03	
Variable	−19.5297	6.7242		−0.1117	0.1746	−0.3569	1.1657	−1.0893	0.2491	−0.2213		−0.2343		
Cost		(7.90)		(3.92)	(6.52)	(9.54)	(38.35)	(25.80)	(5.74)	(3.48)		(6.69)		
LTVC														0.933
Fixed													2142.24	
Cost	−51.8255	13.8378	−0.5743		0.2213	−1.4575	1.6983	−2.0518	0.4303	0.2087	−0.5163	0.1869		
LFC		(14.42)	(2.95)		(5.65)	(27.80)	(41.06)	(34.22)	(7.56)	(2.60)	(2.58)	(3.82)		0.951

[1]The L prefix to the variable names indicates that it has been transformed to a natural logarithm.
YR: Year the survey was conducted.
FA, FB: Above average (1,0), average (0,0), or below average (0,1) fishing year.
DG, DL: State in which survey was conducted (Texas (1,0), Louisiana (0,1), or West coast Florida (0,0)).
D, D1: Vessel size categories (>50 ft. (1,0), 25-50 ft. (0,0), or <25 ft. (0,1)).
TP: Annual trips by vessel size category.
TD, SD: Source of trip data (NMFS data prior to 1976 (0,1), NMFS data from 1976 to 1980 (0,0), and published survey reports (1,0)).
IOS: Inshore vs. offshore area of vessel operations.

in the pooled data base and the estimated regression equations are based on a common probability distribution, the cost and revenue estimates for vessels operating in the Gulf of Mexico shrimp fishery are comparable.

The Econometric Model

Cost and revenue data from vessels participating in the Gulf of Mexico shrimp fishery were used in a weighted least squares regression analysis. To provide a consistent set of data for estimating cost and revenue trend lines, the survey data were organized into categories reflecting total revenue (TR), the value of the shrimp harvested by the vessel; catch expense (CE), the labor component of variable costs that is directly related to the level of harvest; effort expense (EE), the remaining variable costs that are caused by the fishing activity; total variable cost (TVC), the cost that accrued to the firm due to the level of fishing activity; fixed cost (FC), the overhead expense that accrued to the firm regardless of the level of fishing activity; and total cost (TC), the sum of variable and fixed costs. The total revenue and catch expense categories were adjusted for inflation to a 1977 base year by the producer price index (PPI) for meat, poultry, and fish; effort expense by the intermediate materials and supplies PPI; and fixed costs by the agricultural machinery and equipment PPI. Real variable cost was calculated as the total of adjusted catch and effort expense, and real total cost was the sum of adjusted fixed cost and real variable cost.

These real costs and revenues (dependent variables) were regressed against quantitative and qualitative (dummy) independent variables (Draper and Smith, 1981:3, 71) to explain the variation in the cost and revenue structure of shrimp fishing firms. The independent variables were created from information primarily provided by the published survey results and augmented with data collected by NMFS on the Gulf of Mexico shrimp fisheries. Based on the historic catch and revenue information maintained by NMFS for the shrimp fishery and the economic theory of the firm utilizing a common property resource, a logarithmic functional form (Chiang, 1974:301-303)[1] for the model should provide the best statistical fit to the combined survey data. The historical information indicates that the mean shrimp catch appears to have reached a horizontal asymptote with respect to the factor inputs and technology used in the production process. Since real total revenue received by the firm is determined in part by the quantity produced, the revenue trend lines should conform to the shape of the production function. The cost trend lines should also conform to a logarithmic functional form since the surveys collected cost information from firms that have already reacted to the economic signals in the marketplace and are at or near the theoretical equilibrium where average cost equals average revenue for a common property resource. Even though the actual, underlying cost and revenue functions are not estimated, both the cost and revenue trend lines should conform to the general shape of the production function constraint that appears to be best explained by a logarithmic function. The natural logarithms of the dependent and independent variables[2] were used in a weighted least squares regression analysis, and the results are presented in Table 1. The coefficient of determination adjusted for the

[1]Alternative inherently linear functional forms were also fitted to the data, but the logarithmic function provided the best statistical fit.

[2]Since the natural logarithm of zero is undefined, care must be taken in transforming dummy variables to correspond to a logarithmic function. The data base can be altered so that the dummy variables have values of 1 and 2.718 that are transformed by natural logarithms to 0 to 1, respectively. The resulting regression coefficients, however, provide the same result as that derived when the coefficient and the unaltered dummy variable data (0 and 1) are used in the transformed linear logarithmic model.

degrees of freedom (R^2) range from 88.1 to 95.1 percent and the reported F statistics indicate that each equation is statistically significant.

The coefficients provide empirical estimates of the change in costs and revenues due to a unit change in the independent variables. The (LYR) variable represents the year in which the published survey was conducted and has a statistically significant, positive impact on both the level of operating costs and revenues. The value of the coefficient indicates the increase in the estimated value of revenue or cost for each one year increment in time. Since these data were adjusted for inflation by the PPI, the (LYR) variable was expected to be insignificant. This variable may have acted as a proxy variable, however, being correlated with important omitted descriptive variables in the specification of the model. These omitted variables could be the actual physical quantities of the factor inputs consumed in the fishing operation, changes in the production technology, or changes in the stock of fish being harvested.

The qualitative variables (DG) and (DL) indicate the region within the Gulf of Mexico where the studies were conducted. If the survey was conducted for vessels operating out of Texas, (DG=1) and (DL=0); Louisiana, (DG=0) and (DL=1); and west coast of Florida, (DG=0) and (DL=0). The coefficients of these variables indicate that vessels operating out of Louisiana had lower real revenues and costs than vessels operating out of Florida or Texas. Also, Texas vessels had higher revenues and costs than vessels operating in Louisiana and Florida. These variables could be reflecting differences between regions in vessel characteristics and perhaps in the size or species of shrimp landed. The coefficient of a related variable (IOS), which separates inshore (IOS=1) from offshore (ISO=0) areas of operation, indicates that the variable costs and the total revenue for inshore operations were lower than those offshore. The lower inshore variable costs may be caused by the lower catch expense, which like revenue would be reduced if catch rates or prices were lower for inshore fisheries. Since these variables are highly correlated, suggesting the existence of multicollinearity, care should be taken in interpreting the individual coefficient's effect on the dependent variable (Intriligator, 1978:151-156).

The variables (D) and (D1) separate the survey data into size categories reflecting the reported vessel hull lengths of >50 feet, (D=1) and (D1=0); between 25 and 50 feet, (D=0) and (D1=0); and <25 feet, (D=0) and (D1=1). The estimated coefficients indicate that >50 foot vessels had higher costs and revenues and <25 foot vessels had lower costs and revenues than 25-50 foot vessels. The change in the adjusted coefficient of determination (not reported here) indicated that the vessel length variables explained between one-third and one-half of the variation in the cost and revenue data. Costs and revenue, therefore, appear to vary more by vessel length than by any other independent variable. This may be caused by a high correlation between vessel length and other vessel characteristics, such as horsepower, length of trip, and amount of gear.

The type of fishing year variables (FA) and (FB) represent above average fishing years, (FA=1) and (FB=0), average fishing years, (FA=0) and (FB=0), and below average fishing years, (FA=0) and (FB=1)[3]. The coefficient for (FB) suggests that total revenue falls in below average fishing years probably as a result of declines in catch, price per pound landed, or some combination of both. The increase in effort expense may be the result of attempts by fishermen to maintain their market share of the harvest. The decline in variable costs probably results from a decline in the catch expense that would occur for reasons similar to the decline in total revenue. The (FA) variable was insignificant in all equations except for the fixed cost equation, which is discussed subsequently.

The (LTP) variable indicates the average number of trips made per year by vessels of lengths corresponding to variables (D) and (D1). The average trips per year variable (LTP) had a positive impact in the equations, suggesting that both revenues and variable costs increase as the number of trips increase with revenues increasing slightly faster than costs. Variables (TD) and (SD) indicate the source of this average trip per year data. If the data were provided in the survey reports, (TD=1) and (SD=0); from NMFS census data prior to 1976, (TD=0) and (SD=1); and from NMFS survey data from 1976 to 1980, (TD=0) and (SD=0). The coefficients of these variables indicate that the trip data in the cost and returns surveys are statistically different from the NMFS data. This may have occurred because the NMFS average trips reflects the entire fleet of shrimp vessels in the Gulf of Mexico rather than the annual number of trips in the published surveys collected from only the surveyed vessels.

Because fixed costs accrue regardless of the level of output, none of the independent variables in the fixed cost equation should have been significant. Fixed cost should be a function of vessel age, interest rate on the construction loan, insurance, depreciation, and overhead. The statistical significance of these misspecified variables may be caused by a high correlation with the omitted variables in the model specification. For example, the (LYR) variable would be highly correlated with the entry of new shrimp vessels into the fishery. These new vessels would have higher fixed costs of operation caused by higher construction loan interest rates and construction costs. Unfortunately, the survey results do not provide sufficient information on these omitted variables to include them in the model.

Discussion

A model with a good statistical fit is

[3]The type of fishing year was based on the total value of the shrimp landed. An above average fishing year was determined to be a shrimp harvest valued in excess of $250 million, an average fishing year had a value between $100 and $250 million, and a below average year was valued at less than $100 million in constant dollars with a 1977 base year. These categories were chosen after considering both the biological and economic conditions existing during years that industry analysts indicated were above average, average, and below average. A year when pounds landed were low, for example, could still be above average if prices were exceptionally high.

Table 2.—Estimated cost and return values[1].

Item	Texas >50′	Texas 50′ - 25′	Texas <25′	Louisiana >50′	Louisiana 50′ - 25′	Louisiana <25′	Florida >50′	Florida 50′ - 25′	Florida <25′
Offshore vessels for 1971									
Total revenue	$96,817.00	$31,194.90	$5,564.90	$62,826.60	$20,243.00	$3,611.20	$83,565.50	$26,925.10	$4,803.20
Catch expense	$36,008.80	$11,698.40	$5,161.70	$13,190.20	$4,313.00	$2,433.00	$31,683.80	$10,288.40	$4,443.40
Effort Expense	$37,355.10	$12,005.80	$2,813.70	$29,925.50	$9,617.90	$2,254.10	$29,925.50	$9,617.90	$2,254.10
Total variable cost	$73,363.90	$23,704.20	$7,975.40	$43,115.70	$13,930.90	$4,687.10	$61,609.30	$19,906.30	$6,697.50
Fixed cost	$18,468.50	$3,595.80	$462.10	$3,445.90	$670.90	$86.20	$14,801.40	$2,881.80	$370.30
Total cost	$91,832.40	$27,300.00	$8,437.50	$46,561.60	$14,601.80	$4,773.30	$76,410.70	$22,788.10	$7,067.80
Profit	$4,984.60	$3,894.90	($2,872.60)	$16,265.00	$5,641.20	($1,162.10)	$7,154.80	$4,137.00	($2,264.60)
Relative cost index	0.95	0.88	1.52	0.74	0.72	1.32	0.91	0.85	1.47
Offshore vessels for 1972									
Total revenue	$113,644.30	$36,991.30	$6,598.90	$73,746.20	$24,004.40	$4,282.20	$98,089.50	$31,928.20	$5,695.70
Catch expense	$42,298.80	$13,987.80	$5,969.90	$16,639.70	$5,579.00	$2,889.40	$37,010.90	$12,225.30	$5,125.60
Effort expense	$38,513.40	$12,378.10	$2,901.00	$30,853.40	$9,916.20	$2,324.00	$30,853.40	$9,916.20	$2,324.00
Total variable cost	$80,812.20	$26,365.90	$8,870.90	$47,493.10	$15,495.20	$5,213.40	$67,864.30	$22,141.50	$7,449.60
Fixed cost	$22,515.00	$4,457.90	$572.90	$4,201.00	$831.80	$106.90	$18,044.50	$3,572.70	$459.10
Total cost	$103,327.20	$30,823.80	$9,443.80	$51,694.10	$16,327.00	$5,320.30	$85,908.80	$25,714.20	$7,908.70
Profit	$10,317.10	$6,167.50	($2,844.90)	$22,052.10	$7,677.40	($1,038.10)	$12,180.70	$6,214.00	($2,213.00)
Relative cost index	0.91	0.83	1.43	0.70	0.68	1.24	0.88	0.81	1.39
Offshore vessels for 1973									
Total revenue	$81,553.70	$25,962.00	$4,634.90	$52,921.90	$16,860.20	$3,007.70	$70,391.30	$22,425.80	$4,000.50
Catch expense	$28,930.30	$9,803.30	$4,850.30	$8,083.60	$2,517.20	$2,090.20	$27,803.50	$8,820.50	$4,211.00
Effort expense	$47,298.50	$15,201.60	$3,562.70	$37,891.20	$12,178.10	$2,854.10	$37,891.20	$12,178.10	$2,854.10
Total variable cost	$76,228.80	$25,004.90	$8,413.00	$45,974.80	$14,695.30	$4,944.30	$65,694.70	$20,998.60	$7,065.10
Fixed cost	$26,619.90	$5,087.20	$653.70	$4,966.90	$949.20	$122.00	$21,334.40	$4,077.10	$523.90
Total cost	$102,848.70	$30,092.10	$9,066.70	$50,941.70	$15,644.50	$5,066.30	$87,029.10	$25,075.70	$7,589.00
Profit	($21,295.00)	($4,110.10)	($4,431.80)	$1,980.20	$1,215.70	($2,058.60)	($16,637.80)	($2,649.90)	($3,588.50)
Relative cost index	1.26	1.16	1.96	0.96	0.93	1.68	1.24	1.12	1.90
Offshore vessels for 1974									
Total revenue	$92,463.40	$30,000.30	$5,351.80	$60,001.50	$19,467.80	$3,472.90	$79,807.70	$25,894.10	$4,619.20
Catch expense	$34,765.00	$11,496.00	$5,466.60	$10,032.90	$3,414.10	$2,429.50	$31,079.00	$10,259.60	$4,732.70
Effort expense	$48,724.60	$15,659.90	$3,670.10	$39,033.70	$12,545.30	$2,940.10	$39,033.70	$12,545.30	$2,940.10
Total variable cost	$83,489.60	$27,155.90	$9,136.70	$49,066.60	$15,959.40	$5,369.60	$70,112.70	$22,804.90	$7,672.80
Fixed cost	$30,702.10	$6,046.70	$777.00	$5,728.60	$1,128.20	$145.00	$24,606.00	$4,846.10	$622.70
Total cost	$114,191.70	$33,202.60	$9,913.70	$54,795.20	$17,087.60	$5,514.60	$94,718.70	$27,651.00	$8,295.50
Profit	($21,728.30)	($3,202.30)	($4,561.90)	$5,206.30	$2,380.20	($2,041.70)	($14,911.00)	($1,756.90)	($3,676.30)
Relative cost index	1.23	1.11	1.85	0.91	0.88	1.59	1.19	1.07	1.80
Offshore vessels for 1975									
Total revenue	$95,479.40	$31,500.00	$5,619.30	$61,958.60	$20,441.00	$3,646.50	$82,410.90	$27,188.50	$4,850.20
Catch expense	$31,381.20	$10,827.10	$5,289.10	$7,734.90	$2,921.60	$2,301.80	$28,293.30	$9,715.90	$4,587.80
Effort expense	$50,173.70	$16,125.60	$3,779.20	$40,194.60	$12,918.40	$3,027.60	$40,194.60	$12,918.40	$3,027.60
Total variable cost	$81,554.90	$26,952.70	$9,068.30	$47,929.50	$15,840.00	$5,329.40	$68,487.90	$22,634.30	$7,615.40
Fixed cost	$30,377.10	$6,149.70	$790.30	$5,667.90	$1,147.40	$147.40	$24,345.50	$4,928.60	$633.30
Total cost	$111,932.00	$33,102.40	$9,858.60	$53,597.40	$16,987.40	$5,476.80	$92,833.40	$27,562.90	$8,248.70
Profit	($16,452.60)	($1,602.40)	($4,239.30)	$8,361.20	$3,453.60	($1,830.30)	($10,422.50)	($374.40)	($3,398.50)
Relative cost index	1.17	1.05	1.75	0.87	0.83	1.50	1.13	1.01	1.70
Offshore vessels for 1976									
Total revenue	$109,683.00	$38,276.50	$6,828.20	$71,175.60	$24,838.50	$4,430.90	$94,960.50	$33,037.60	$5,893.60
Catch expense	$40,539.00	$15,319.20	$6,576.30	$14,575.50	$6,030.50	$3,168.10	$35,715.60	$13,403.40	$5,648.80
Effort expense	$43,338.90	$13,929.00	$3,264.40	$34,719.20	$11,158.60	$2,615.20	$34,719.20	$11,158.60	$2,615.20
Total variable cost	$83,877.90	$29,248.20	$9,840.70	$49,294.70	$17,189.10	$5,783.30	$70,434.80	$24,562.00	$8,264.00
Fixed cost	$25,552.30	$5,675.20	$729.30	$4,767.70	$1,058.90	$136.10	$20,478.70	$4,548.30	$584.50
Total cost	$109,430.20	$34,923.40	$10,570.00	$54,062.40	$18,248.00	$5,919.40	$90,913.50	$29,110.30	$8,848.50
Profit	$252.80	$3,353.10	($3,741.80)	$17,113.20	$6,590.50	($1,488.50)	$4,047.00	$3,927.30	($2,954.90)
Relative cost index	1.00	0.91	1.55	0.76	0.73	1.34	0.96	0.88	1.50
Offshore vessels for 1977									
Total revenue	$121,544.30	$42,008.30	$7,493.90	$78,872.70	$27,260.10	$4,862.90	$104,908.30	$36,258.60	$6,468.20
Catch expense	$43,179.40	$15,993.40	$6,844.30	$15,859.50	$6,340.50	$3,305.50	$37,985.40	$13,985.00	$5,877.50
Effort expense	$44,593.70	$14,332.20	$3,358.90	$35,724.40	$11,481.70	$2,690.90	$35,724.40	$11,481.70	$2,690.90
Total variable cost	$87,773.10	$30,325.60	$10,203.20	$51,583.90	$17,822.20	$5,996.40	$73,709.80	$25,466.70	$8,568.40
Fixed cost	$28,451.50	$6,219.20	$799.20	$5,308.60	$1,160.40	$149.10	$22,802.30	$4,984.40	$640.50
Total cost	$116,224.60	$36,544.80	$11,002.40	$56,892.50	$18,982.60	$6,145.50	$96,512.10	$30,451.10	$9,208.90
Profit	$5,319.70	$5,463.50	($3,508.50)	$21,980.20	$8,277.50	($1,282.60)	$8,396.20	$5,807.50	($2,740.70)
Relative cost index	0.96	0.87	1.47	0.72	0.70	1.26	0.92	0.84	1.42
Offshore vessels for 1978									
Total revenue	$140,549.90	$45,830.80	$8,175.80	$91,205.80	$29,740.60	$5,305.40	$121,312.50	$39,557.80	$7,056.70
Catch expense	$49,861.00	$16,544.10	$7,071.40	$19,514.30	$6,576.80	$3,418.50	$43,645.70	$14,463.40	$6,071.90
Effort expense	$45,867.80	$14,741.80	$3,454.90	$36,745.20	$11,809.80	$2,767.80	$36,745.20	$11,809.80	$2,767.80
Total variable cost	$95,728.80	$31,285.90	$10,526.30	$56,259.50	$18,386.60	$6,186.30	$80,390.90	$26,273.20	$8,839.70
Fixed cost	$34,013.40	$6,754.40	$868.00	$6,346.40	$1,260.30	$161.90	$27,259.90	$5,413.30	$695.60
Total cost	$129,742.20	$38,040.30	$11,394.30	$62,605.90	$19,646.90	$6,348.20	$107,650.80	$31,686.50	$9,535.30
Profit	$10,807.70	$7,790.50	($3,218.50)	$28,599.90	$10,093.70	($1,042.80)	$13,661.70	$7,871.30	($2,478.60)
Relative cost index	0.92	0.83	1.39	0.69	0.66	1.20	0.89	0.80	1.35

Continued on next page.

Table 2.—Estimated cost and return values[1]—Continued.

Item	Texas >50′	Texas 50′ - 25′	Texas <25′	Louisiana >50′	Louisiana 50′ - 25′	Louisiana <25′	Florida >50′	Florida 50′ - 25′	Florida <25′
				Offshore vessels for 1979					
Total revenue	$260,157.90	$65,064.70	$11,606.90	$168,822.00	$42,221.80	$7,532.00	$224,549.50	$56,159.10	$10,018.20
Catch expense	$116,585.00	$26,378.00	$10,422.40	$58,451.80	$12,267.50	$5,367.10	$99,729.10	$22,737.80	$8,889.90
Effort expense	$47,161.50	$15,157.50	$3,552.40	$37,781.50	$12,142.80	$2,845.80	$37,781.50	$12,142.80	$2,845.80
Total variable cost	$163,746.50	$41,535.50	$13,974.80	$96,233.30	$24,410.30	$8,212.90	$137,510.60	$34,880.60	$11,735.70
Fixed cost	$88,431.50	$11,335.80	$1,456.70	$16,500.00	$2,115.10	$271.80	$70,872.80	$9,085.00	$1,167.50
Total cost	$252,178.00	$52,871.30	$15,431.50	$112,733.30	$26,525.40	$8,484.70	$208,383.40	$43,965.60	$12,903.20
Profit	$7,979.90	$12,193.40	($3,824.60)	$56,088.70	$15,696.40	($952.70)	$16,166.10	$12,193.50	($2,885.00)
Relative cost index	0.97	0.81	1.33	0.67	0.63	1.13	0.93	0.78	1.29
				Offshore vessels for 1980					
Total revenue	$204,755.80	$62,708.50	$11,186.60	$132,870.40	$40,692.90	$7,259.20	$176,730.50	$54,125.50	$9,655.50
Catch expense	$75,350.50	$22,535.60	$9,172.70	$33,878.10	$9,919.30	$4,611.50	$65,152.10	$19,527.40	$7,844.20
Effort expense	$48,474.70	$15,579.60	$3,651.30	$38,833.50	$12,480.90	$2,925.10	$38,833.50	$12,480.90	$2,925.10
Total variable cost	$123,825.20	$38,115.20	$12,824.00	$72,711.60	$22,400.20	$7,536.60	$103,985.60	$32,008.30	$10,769.30
Fixed cost	$99,673.20	$17,847.50	$2,293.50	$18,597.50	$3,330.10	$427.90	$79,882.50	$14,303.80	$1,838.10
Total cost	$223,498.40	$55,962.70	$15,117.50	$91,309.10	$25,730.30	$7,964.50	$183,868.10	$46,312.10	$12,607.40
Profit	($18,742.60)	$6,745.80	($3,930.90)	$41,561.30	$14,962.60	($705.30)	($7,137.60)	$7,813.40	($2,951.90)
Relative cost index	1.09	0.89	1.35	0.69	0.63	1.10	1.04	0.86	1.31

[1]These estimated values are calculated from the regression equations in Table 1 using NMFS trips data rather than the trips reported in the published surveys. This table provides interpolative information not found in the published reports and the real cost and revenue estimates for different years, regions, vessel sizes, and areas of operation are comparable. Catch expense is calculated by subtracting the estimated effort expense value from the estimated total variable cost value for a given state and size category. Total cost is calculated by adding the estimated values for total variable cost and fixed cost. Profit is the difference between estimated total revenue and total cost. The relative cost index is calculated by dividing estimated values of total cost by total revenue. It provides a measure of the direction and magnitude of the change in operating costs relative to revenue. An increase in relative costs can occur from either an absolute increase in costs with revenues held constant or an absolute decrease in revenue with costs held constant. When the relative cost index is >1.00, relative costs have increased; when it is = 1.00 there is no change in relative costs; and when it is <1.00, relative costs have declined. Although a relative revenue index (TR/TC) would provide the same type of information, a relative cost index (TC/TR) is conceptually easier to convert to a profit rate

$$= (TR - TC)/TR = [(1 - TC/TR) \times 100]$$

than is a relative revenue index

$$= (1 - 1/[TR/TC]) \times 100).$$

further enhanced when it conforms to what is known about the economics of the industry in both applied and theoretical terms. The independent variables in this model specification account for the known trends in cost and revenue and can be relied upon to provide fairly accurate aggregate estimates for the financial performance of firms in the Gulf of Mexico shrimp fishery.

The unexplained variance in the regression equations may be due to some violation of the implicit assumptions used in developing the model. The vessels surveyed were assumed to be independent, owner-operated, single species fishing firms operating competitively. Some of the surveyed vessels, however, may actually be multiple species, vertically or horizontally integrated, nonowner-operated fishing firms that do not conform to these assumptions. These fishing firm ownership types could each have a different cost-revenue structure associated with it. For example, a vertically integrated firm could operate its fishing vessels at a loss to maximize profits at some other level within the firm. Without information from the surveys on the organization of the firm, the remaining variation could not be accounted for in the model specification.

The estimated real costs for fishing firms operating in the Gulf of Mexico shrimp fishery have increased from 1971 to 1980 (Table 2). Real revenues have also increased over this time period resulting in only 3 years (1973, 1974, and 1975) when the weighted average relative cost index for regions, vessel sizes, and areas of operation indicates that losses have occurred (Table 3). The relative cost index number of 0.921, weighted for all vessel sizes, years, regions, and areas of operation, indicates that the fishery has been profitable (7.9 percent rate of return over total costs; see footnotes to Table 2) for firms during the 1971-80 time period.

The firms with the best financial performance, lowest relative cost index in Table 2, were the 25-50 foot vessels. The financial performance of this size vessel may have resulted from economies of scale in the fishing operation and from increased operating flexibility that allows these vessels to operate both inshore and offshore as conditions in the fishery dictate. Larger and smaller vessels may be less efficient in utilizing the factor inputs in the fishing process and also may not be able to take advantage of better fishing conditions outside their fishing areas. The vessels <25 feet in length operating

Table 3.—Comparison of the Relative Cost Index to the size of the offshore fishing fleet.

Year	Relative Cost Index	Number of vessels reported in the Gulf of Mexico shrimp fishery
1971	0.8934	3,487
1972	0.8519	3,683
1973	1.1830	4,091
1974	1.1379	3,785
1975	1.0796	3,690
1976	0.9304	4,177
1977	0.8890	4,335
1978	0.8525	4,607
1979	0.8669	5,051
1980	0.9463	5,107
1981		5,205

out of Texas, Louisiana, and Florida ports take a higher proportion of their total revenue in terms of catch expense (wages, salaries, packing fees, etc.) than the larger vessels. This may have resulted from the smaller vessels being one-man, part-time operations with fishermen wishing to make a higher relative income in the short run. Large vessels had their best financial performance operating out of Louisiana. Only in Louisiana did large vessels make a profit in inshore operations; Louisiana large vessels had a relative cost advantage in offshore operations.

When the weighted relative cost index for the offshore fleet was compared to the number of vessels operating in the Gulf of Mexico shrimp fishery (Table 3) as a measure of fishing effort, declines in the relative costs of fishing were usually accompanied in the next year by an increase in the number of vessels operating in the fishery. Increases in the relative cost index were followed in the next year by declines in the number of vessels. For example, the 1973 relative cost index of 1.1830 indicates operating costs were 18 percent higher than revenues, and fishing firms experienced a financial loss (profits $= (1-TC/TR) \times 100 = (-0.1830) \times 100 = -18.30$ percent) that was followed in 1974 by a decline in the number of operating vessels. The real costs and revenues, therefore, appear to be acceptable estimates of the financial condition of fishing firms operating in the Gulf of Mexico fishery.

The close relationship between the fishing firms relative cost index and the number of vessels in the Gulf of Mexico shrimp fishery ($r = -0.46$) suggests that the financial condition of the firm rather than the fisherman's personal income determines whether fishing effort increases or declines. The profit maximizing objective of the firm would, therefore, be of secondary importance relative to the objectives of minimizing the entrance of new fishing firms or of maintaining or improving its relative market share of the shrimp resource. The firm's failure to maximize profit, however, could result in a nonoptimal allocation of resources for the industry.

Conclusions

Since detailed cost data are not routinely collected and the published survey data from various sources are not easily compared, trends in costs and revenues for the Gulf of Mexico shrimp fishing fleet cannot be readily determined. A consistent data set for comparing vessel operating costs and revenues between states, vessel sizes, and years was estimated using weighted least squares regression analysis. Differences in the sample variance between the published cost and revenue data caused by time, type of survey, region surveyed, vessel size, sample size, or area of operation are accounted for in the econometric model. The coefficient of determination adjusted for the degrees of freedom (r^2) and the F statistic (Table 1) indicate that the model specification provides a good statistical fit to the survey data.

The cost and revenue estimates suggest that fishing firms in the Gulf of Mexico shrimp fishery have generally been profitable over the time period of the analysis, exclusive of opportunity costs. Medium sized vessels (25-50 feet) exhibited the best financial performance. Smaller vessels (<25 feet) took a larger proportion of total revenue as catch expense. Of the states included in the analysis, vessels in Louisiana for all size classes seemed to have a relative cost advantage. Comparisons of the relative cost index and the number of vessels reported operating in the Gulf of Mexico shrimp fishery suggest that these cost and revenue trends are indicative of changes in fishing effort levels.

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Changes of Myofibrillar Proteins and Texture in Freshwater Prawn, *Macrobrachium rosenbergii*, During Iced Storage

H. W. KYE, W. K. NIP and J. H. MOY

Introduction

Shelf life of ice-chilled freshwater prawn, *Macrobrachium rosenbergii* has been reported to be 3-4 days with development of mushiness at the proximal end (Sidwell, 1977; Nip et al., 1985a). Microstructural changes as related to development of mushiness has been demonstrated (Nip and Moy, 1988). Proteolysis of muscle proteins by proteolytic and/or collagenolytic enzymes has been postulated as the main mechanism which contributes to postmortem mushiness in freshwater prawn (Rowland et al., 1982; Baranowski et al., 1984; Nip et al., 1985b; Premaratne et al., 1986). However, the nature of this protein degradation is not fully understood. Reports on changes of prawn/shrimp protein components have been very limited. Wong (1982) studied the microstructural changes in muscles in penaid shrimp during iced storage and demonstrated myofibrillar breakdown, especially Z-lines and sarcoplasmic reticular degradation.

Objective/instrumental methods have been used successfully in assessing the textural quality in shrimp and prawn (Ma et al., 1983; Soo and Sander, 1977; Ahmed et al., 1972; Angel et al., 1985; Tillman and Finne, 1983; Waters and Hale, 1981; Nip and Moy, 1981). Nip et al. (1985b) reported that the texture, as measured by the PEP Texture Tester[1] (PEP Co., Houston, TX), showed significant softening with ice chilling time and was related to the mushiness problem in *M. rosenbergii*.

Relationship on structural protein degradation and textural changes in prawn or shrimp has not been reported. The purpose of this study was to investigate the degradation of myofibrillar proteins and the textural changes in freshwater prawn, *M. rosenbergii*, and their relationship during iced storage.

ABSTRACT—Changes in myofibrillar proteins and texture of freshwater prawn, Macrobrachium rosenbergii, *during 14-day iced storage were studied. Degradation of myofibrillar proteins with 113,000, 103,000, and 80,000 daltons and an increase of 25,000 and 31,000 dalton protein subunits were observed during iced storage of the prawns. Significant changes in texture of the ice-stored and cooked prawn muscle were demonstrated. Relationship of myofibrillar protein degradation and textural changes are discussed.*

Materials and Methods

Muscle Samples

Freshly harvested live prawns averaging 78 g in weight and 200 mm in length (tip of rostrum to tip of telson) were obtained from a local (Honolulu, Hawaii) market and held in a tank with running tap water overnight at ambient temperature (20°-23°C). The prawns were killed by placing them in an ice slurry. Upon death, whole prawns were stored in slush ice in an insulated container at 0°C. After 0, 1, 3, 5, 7, 10, and 14 days of storage, the abdomen (tail) muscle was separated from the shell and head and then sectioned. After a brief washing with distilled water, the first proximal segment (section in the vicinity of the stomach) and/or the third proximal segment (the third section away from the stomach) from three prawns were pooled and subject to protein extraction.

[1]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

Protein Extraction

The first and third segments from the prawns stored for 0, 1, 3, 5, 7, and 14 days were subject to myofibrillar isolation according to the procedure of Olson et al. (1977). Myofibril suspensions were then brought to 50 percent glycerol (w/w) and placed in the freezer at −20°C for 2-14 days. At the end of the iced storage period, the myofibril suspensions were analyzed within 2-3 days.

Protein Determination

The protein concentrations of all samples were determined according to the Bio-Rad Protein Assay (Bio-Rad Lab., Richmond, Calif.) with bovine gamma globulin as the standard.

Protein Electrophoresis

Polyacrylamide gel electrophoresis was performed in the presence of sodium dodecyl sulfate (SDS) according to the procedures of Porzio and Pearson (1977) except that a Bio-Rad Protean slab gel was used rather than a rod gel. The marker dye was 0.005 percent bromophenol blue.

A 26 μg protein sample extracted from

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the prawn muscles stored for 0, 1, 3, 7, and 14 days at 0°C was applied to each sample well. A Bio-Rad silver staining kit (Bio-Rad Lab., Richmond, Calif.) was used to stain the slab gels.

Textural Changes

The prawn samples obtained from the same source (killed and stored in similar manner as described above for 0, 1, 3, 5, 7, and 14 days at 0°C) were cooked in boiling water for 5 minutes. After the heads and shells were removed, the first and third segments were further sectioned into halves parallel with the muscle fibers. Another set of prawn samples was treated as described above except for the heat treatment.

The PEP Texture Tester equipped with a standard multiple-blade shearing cell was used to measure forces required to shear individual samples. Each sample was placed on the platform so that the cut face was made contact with the stationary shearing cell and the muscle fibers were perpendicular to the moving cell. Data were recorded as the force-distance curve and total integrated work (force-distance) required to compress, shear, and push the sample through (a combination of adhesive and cohesive forces is encountered as the sample is pushed through the stationary cell). There were 10-24 replicates for each treatment.

Statistical analyses (i.e., the analysis of variance, correlation coefficients, and regression analysis) were conducted on the textural measurement data to determine the significance of textural changes in *M. rosenbergii* during cold storage.

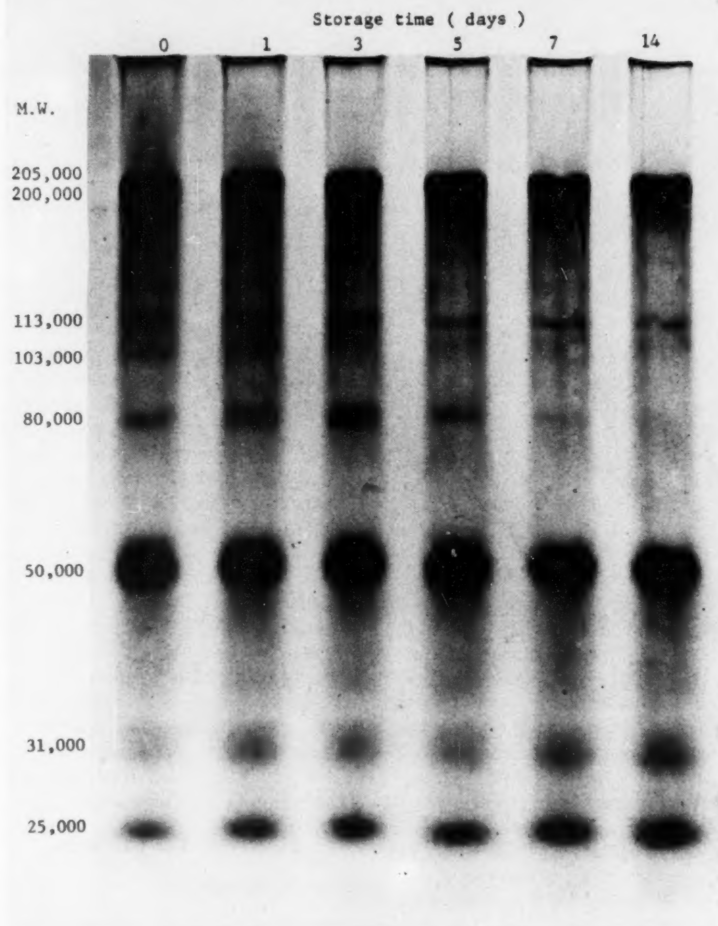

Figure 1.—The effects of iced storage on the electrophoretic patterns of myofibrillar proteins extracted from the first segment of the freshwater prawn.

Results and Discussion

SDS-PAGE of Myofibrillar Proteins

The results of SDS-PAGE of myofibrillar proteins from the first segment of prawn stored for various periods at 0°C are shown in Figure 1. An identical pattern was obtained for the third segment.

Extensive protein degradation occurred during 14 days of iced storage (Fig. 1): The decrease in intensity of the 113,000 and 80,000 dalton subunits during the 14-day iced storage and a complete dissolution of α-actinin (103,000 daltons) after 3 days of iced storage (Fig. 1).

Myosin heavy chains have been known to be very stable myofibrillar components. Degradation of this component has been reported only under specific or controlled conditions, such as at an acidic pH to investigate lysosomal proteolytic reaction (Dutson, 1982), at a high temperature to study the nature of major contractile proteins (Betchel and Parrish, 1983) or from a specific animal such as the squid (Stanley and Hultin, 1984). The gradual disappearance of these heavy chain subunits implies the existence of a highly-active enzyme system in the freshwater prawn during iced storage.

The protein α-actinin and its postmortem changes are also known to be barely detectable. Studies have shown that α-actinin is released from the Z-line as a result of partial degradation of my-

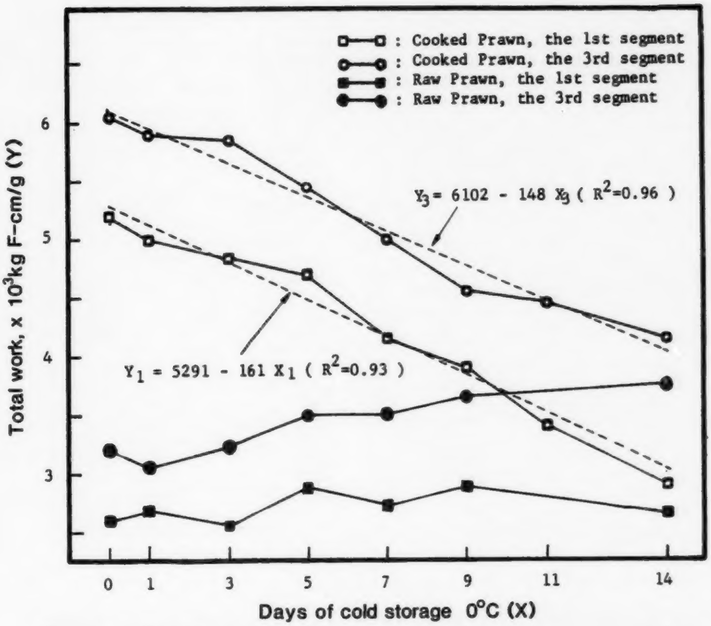

Figure 2.—The effects of iced storage and subsequent heat treatment on the texture (firmness or softness expressed as the total work required for shearing a given sample in a PEP Texture Tester) of different segments of the freshwater prawn tail muscle. Each point represents a mean of 10-24 replicates.

ofibril caused by a calcium-activated enzyme (Dayton et al., 1976, Nagainis and Wolfe, 1982). This phenomenon has been considered as one of the most important events that cause myofibril fragmentation. Observations on the dissolution of α-actinin are quite limited: A very slight decrease during the postmortem storage of bovine muscle (Goll et al., 1977) or the occurrence of dissolution at 37°C (Betchel and Parrish, 1983).

In this study, the disappearance of the α-actinin band after 3 days of cold storage is a significant observation and is in agreement with the microstructural changes in ice-chilled prawn (Nip and Moy, 1988). This postmortem change in the freshwater prawn might be useful in determining its storage history when it is iced.

An increase in intensity of bands with 25,000 and 31,000 daltons during iced storage was clearly demonstrated (Fig. 1). The increase in these lower molecular weight proteins corresponds to the decrease in the higher molecular weight proteins.

From this experiment, it is apparent that extensive myofibrillar protein degradation occurs during the first few days of iced storage.

Texture Measurements

The results of texture measurement are shown in Figure 2, demonstrating significant differences ($P \leq 0.01$) between the cooked segments and among the days of iced storage.

Maximum firmness of cooked prawn tissues can be obtained right after death (Fig. 2). Both the raw and cooked samples of the first segment are softer than those of the third segment (Fig. 2). The rate of textural deterioration in the cooked prawn tissues is higher in the first segment than the third segment by about 9 percent (Fig. 2). The cooked prawn tissues lose an average of 11 percent of their original firmness during the first 4 days of iced storage, as measured by the PEP Texture Tester (Fig. 2). This is considerably less than that reported by Waters and Hale (1981).

The textural change is clearly related to the myofibrillar protein degradation reported in the previous sections. The decrease in work (force-distance) values during the first 3 days (Fig. 2) coincides with the complete dissolution of the α-actinin (103,000 daltons) (Fig. 1). The change of texture deterioration after 7 days also coincides with the complete disappearance of the 80,000-dalton band.

The results of statistical analyses show significant correlations between the differences of cooked muscle texture and the duration of iced storage: r = −0.96 and r = −0.98 for the first and third segments, respectively.

These results strongly imply the diminishing effect of the degraded proteins, which contribute to mechanical strength, and in part in a consequence of the proteolytic reaction during iced storage.

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U.S. and Canada Sign Free Trade Agreement

On 4 October 1987, trade representatives of the United States signed an historic trade agreement with Canada. The primary objective of the Free Trade Agreement (FTA) is the eventual elimination of bilateral tariffs within 10 years, beginning 1 January 1989. The FTA, also addresses specific trade issues, affecting agriculture, alcoholic beverages, energy, automobiles, services (e.g., telecommunications), financial services, investment, intellectual property, culture (e.g., printed and recorded material), customs procedures, government procurement, personnel movement, product standards, and import safeguards.

With respect to the elimination of duties, products have been assigned to one of three tariff elimination categories: 1) Immediate, 2) 5-years (20 percent/year), and 3) 10-years (10 percent/year). Most tariffs on fish and fish products fall within the 10-year schedule. Table 1 lists some of the seafood items for which U.S. tariffs are scheduled for elimination.

Under the agreement, Canada agreed to make permanent its current policy of not screening new U.S. business investments and to reduce screening of direct acquisitions. This provision should facilitate U.S. investment in fish processing and brokerage facilities in Canada. The agreement also addresses the issue of government procurement by eliminating many "buy national" restrictions and by lowering from $171,000 to $25,000 the threshold at which open and competitive procedures, as specified under GATT's Government Procurement Code must be followed. This provision will not affect the purchase of fish and fish products through human feeding programs like the surplus commodity program (section 32) of the U.S. Department of Agriculture. However, stiffer competition may develop in the procurement of fish and fish products in Defense Department food acquisition programs.

The agreement also establishes special safeguards designed to protect industries from injury by import competition. If the FTA duty reductions cause injury, the preagreement duty may be reinstated. Section 201 import relief will still be available to industries injured by global imports except that each side will exclude the other from such actions unless its imports are substantial and are found to "contribute importantly" to the injury.

The treatment of subsidies and dumping (U.S. antidumping and countervailing duty laws) was one of the most sensitive and contentious issues in the negotiations. Both parties have agreed to retain existing national laws and procedures dealing with subsidies and dumping. However, both parties did agree to a special binational dispute settlement panel which will replace review by the courts. The panel will apply existing judicial standards of the importing country and decision of the Commerce Department and International Trade Commission can be overturned by the panel if decisions are not supported by substantial evidence or not in accordance with U.S. law.

According to figures released by the Office of the U.S. Trade Representative, Canada exported to the United States a total of $19 billion in dutiable goods out of a total of $68.4 billion in exports to the U.S. Conversely, the United States exported a total of $54 billion to Canada, of which $13.5 billion was dutiable (1985 figures). In terms of fish and fish products, the United States exported a total of $116 million of edible fishery products to Canada while Canada exported about $1 billion in edible fishery products to the United States.

The United States represents a large market outlet for Canadian fishery products while Canada represents a relatively small market for U.S. fishery products. The liberalization of tariff and trade measures should increase the flow of fish and fish products across the U.S.-Canada border; however, given available markets, imports from Canada should show relatively larger increases over the 10-year tariff reduction period. The FTA may enhance the position of certain U.S. fishery brokers dealing in Canadian products as well as U.S. processing firms with investments in Canada and those U.S. processors dependent on the availability of raw product from Canada. The President notified the U.S. Congress of his intention to enter into the Free Trade Agreement on 5 October 1987. The President then had 60 days (by 5 December 1987) to transmit the full agreement to the Congress. In turn, Congress then had 60 days in which to either approve or disapprove of the FTA on an up or down vote (no amendments).

Table 1.—Some seafood items for which U.S. tariffs will be eliminated.

Code	Description	Rate	Advai	Stage
0303.71	Sardines, sardinella	1.1/k	0	10
0304.40	Frozen fillets cod, cusk, haddock	4.134/k	0	5
0305.41	Smoked Pacific, Atlantic & Danube salmon		5%	5
0305.49	Smoked mackerel, including fillets		2.5%	0
0306.24	20 crabmeat, not frozen		7.5%	10
0306.14	20 crabmeat, frozen		7.5%	10
1604.14	10 Tunas and skipjack, whole or in pieces,		35%	10
	20 Tunas and skipjack, not in oil, in airtight containers		6%	10
	30 Tunas and skipjack, not in oil, in airtight containers		12.5%	10
	40 Tunas and skipjack, not in airtight containers	1.10/k		10
	50 Tunas and skipjack, not in airtight containers		6%	10
1604.15	Prepared or preserved mackerel, whole or filleted		6%	5
1604.19	50 fish sticks and like products		15%	10
1605.20	05 Shrimp and prawn product containing fish meat; prepared meals of shrimp and prawn		10%	10

Multispecies Plan Is Extended in New England

Richard B. Roe, Regional Director of the National Marine Fisheries Service (NMFS), announced the approval of the New England Fishery Council's Amendment 1 to the Northeast Multispecies Plan which took effect 1 October 1987 and extended the Plan indefinitely. Revisions to conservation measures in the Amendment will provide greater protection to multispecies stocks. Roe said that this decision implements the foundation of measures which the Council and NMFS can use to rebuild stocks and revitalize the fisheries.

The Regional Director stated that restrictions endured now may reward us someday with a return to the abundant stocks of the past. Over time, as changes and other improvements to the Plan occur, the best of science, knowledgeable fishery advisors, and experienced fishery managers will be embodied. The changes are as follows:

Amendment 1 revisions to
the Multispecies regulations.

1) Permits: Permits now expire each year on 31 December. It is the vessel owner's responsibility to renew the permit each year; however, vessel owners will be informed by the National Marine Fisheries Service (NMFS) when it is time to renew.

2) Relationship to state laws: Provisions have been included that preserve the states' rights to establish management measures which are more restrictive than Federal measures. This means that when state or local regulations differ from Federal regulations, the permitted vessel must comply with the more restrictive requirement.

3) Import prohibitions: It is unlawful to import regulated species (cod, haddock, pollock, witch flounder, yellowtail flounder, American plaice, and winter flounder) which do not meet the minimum length requirements (see no. 8).

4) Southern extension of the large mesh area: The regulated large-mesh area southern boundary is adjusted as follows: Between long. 69°40′W. and 69°00′W., the boundary runs along Loran C 43400; between long. 69°00′W. and 68°00′W., the boundary runs along Loran C 43450; the remainder of the boundary remains unchanged and runs along Loran C 43500.

5) Mesh: The regulated mesh size of $5\frac{1}{2}$ inches for mobile gear now must extend at least 75 continuous meshes forward of the aft end of the cod end. The one-mesh-on-deck provision is interpreted to mean that small mesh stowed and lashed down, or stored on net reels covered and secured, or nets on vessels which have towing wires detached from the gear, are deemed not available for immediate use, and is in compliance with the regulation. The Council and NMFS in consultation with the Atlantic States Marine Fisheries Commission may permit the use of certain selective shrimp fishing gear, with the intention that the gear may reduce juvenile finfish mortality that occurs in that fishery.

6) Closed areas: The dimensions of haddock spawning closed area 1 are changed by eliminating the portion west of long. 69°00′W. and north of lat. 41°30′N. The area is likely to be adjusted further in the future, by covering more ground to the south and east where spawning haddock are located. Scallop dredge gear is prohibited in the southern New England closed area. Hook-and-line gear is allowed, but yellowtail flounder may not be retained.

7) Exempted (small mesh) fishery program: The December/January whiting fishery is limited to the portion of the exempted fishery area which is west of long. 69°00′W. The June through November period no longer allows the 10 percent limit of multispecies to be based on all landed species. The percentage now is based on dogfish, herring, mackerel, ocean pout, red hake, silver hake, and squid. The December through May herring and mackerel exempted fishery is eliminated. Midwater trawling is possible for these species during this period, but under a special permit and with only 1 percent multispecies by-catch.

8) Minimum fish size: Effective 1 October 1987 the minimum fish size for commercially caught cod, haddock, and pollock is 19 inches; for recreationally caught cod and haddock it is 17 inches. Minimum sizes for American dab, witch, and winter and yellowtail flounders remain unchanged. For further information, contact Peter D. Colosi at (617) 281-3600 or Guy Marchesseault at (617) 835-8457.

Penguin Bank Target of Oceanographic Survey

Understanding how an underwater feature, such as Hawaii's Penguin Bank, might influence the physical and chemical properties of seawater was the goal of scientists from the National Marine Fisheries Service's Honolulu Laboratory and University of Hawaii (UH) Department of Oceanography during a late 1987 oceanographic survey aboard the NOAA ship *Townsend Cromwell*. Such information may ultimately lead to a better understanding of how this bank sustains an environment for bottom fisheries, according to Richard S. Shomura, Laboratory director. These bottom fisheries, particularly those for opakapaka and other deep-sea bottom fishes, are of considerable local importance.

Penguin Bank is an elevated, flattop rise extending some 30 n.mi. off the west side of Molokai. The bank's summit lies 150-180 feet below the sea surface, encompassing an area of some 450 n.mi.^{2} During the survey, scientists tracked a current drifter to ascertain the direction and intensity of subsurface current flow over the bank. While following the movement of the current drifter, they collected water samples from various depths for later analyses to determine whether chemical properties of seawater change as a water mass passes over the bank. An example of a possible change in seawater may involve an increase in nutrients over the bank due to upwelling tidal currents.

Scientists also deployed and retrieved sediment traps moored to the northern slope of Penguin Bank. Sediment traps collect particulate matter which slowly sink down through the water column from the overlying water layers. This particulate matter may consist of live planktonic organisms, remnants of dead organisms, or by-products from live organisms. The array moored at Penguin

Bank had a series of 12 sediment traps at each of seven depth layers sampled. Typically sediment traps are used in the open ocean and allowed to drift freely. The anchored sediment trap array at Penguin Bank represented one of only a few instances in which a bank environment was examined in this manner. Data obtained from these sediment traps will provide information on both surface productivity over the bank and the rate at which organic matter is descending to the bottom. Other operations conducted by the scientists involved measurements of seawater temperature and salinity by depth and the collection of bottom samples along the bank for analysis of mineral content.

Shrimp Situation and Outlook Reported

U.S. and Japanese supplies of shrimp reached record levels in 1987. Except for the largest and smallest sizes, prices of shrimp averaged lower than in 1986. Southeastern U.S. landings were 147 million pounds (heads-off) in January-October 1987, 17 percent less than a year earlier, according to preliminary data. They were off 16 percent in the Gulf, and 23 percent in the South Atlantic. Gulf landings could total 160 million pounds, making 1987 an above average year. South Atlantic landings were very low in the normally peak months of July and August, and could total 12.5 million pounds, making 1987 a low year.

Landings in New England could reach 11 million pounds (heads-on) in 1987, up from 10.3 million pounds in 1986. Abundance is reported to be down significantly in the current season (December 1987-May 1988). Pacific landings could reach 83 million pounds (heads-on) in 1987 compared with 62.7 million pounds in 1986, based on strong increases in Oregon and Washington, and assuming no change in California and Alaska. U.S. imports were 327 million pounds in January-September 1987, up 16 percent from a year earlier. Large gains for Ecuador and China changed the ranking of leading suppliers (data in million pounds): Ecuador (73), Mexico (42), China (32), Taiwan (23.3), India (22.9), and Thailand (19.6). Most of the increase of 45 million pounds was for raw headless and raw peeled shrimp (20 million pounds each).

U.S. cold-storage holdings were 7-12 million pounds greater during February-October 1987 than respective monthly holdings in 1986. In part, the increase represents a return to normal levels, since holdings in April-August 1986 were the lowest for these months in twenty years. Holdings in September-October 1987 were the highest for these months since the late 1970's, but the market has grown considerably. Japan imported 365 million pounds of frozen shrimp in January-September 1987, 47 million pounds or 15 percent more than a year earlier. In part, this led to an inventory buildup (+24.5 million pounds through September), the highest since 1981 (+42 million pounds). Japan's inventories have tended to grow faster than the market. In 1987, they averaged 3.5 months of imports versus about two months in the late 1970's.

New York wholesale prices of raw headless Gulf browns reached peaks in mid-1986. Since then, 26-30's to 41-50's trended down, while smaller and larger sizes moved upward to early 1987 and then trended downward (data through November 1987). Dollar equivalents of Tokyo prices of Indian whites behaved similarly, except that prices of some sizes continued upward in 1987 (under-16's and 16-20's) or remained flat (21-25's, 26-30's and 61-70's). Japan's domestic prices (in yen) of these shrimp have trended downward since mid-1985, except for upturns since mid-1987 in the largest two sizes. New York prices of peeled Gulf shrimp moved strongly upward from mid-1986 to early 1987, apparently because of reduced supplies and higher prices for cold-water shrimp.

It is estimated that U.S. consumption of shrimp could be 740 million pounds (heads-off) in 1987, up 4 percent from 708 million pounds in 1986. Increases in 1980-86 averaged 8.5 percent. The underlying 1987 estimates are as follows (data in million pounds, heads-off): landings, 226 (244 in 1986); imports, 560 (492 in 1986); ending holdings, 74 (59 in 1986); and exports, 34 (30 in 1986). This report was prepared by John Vondruska, Southeast Regional Office, National Marine Fisheries Service, NOAA, 9450 Koger Blvd., St. Petersburg, FL 33702.

NOAA Launches Undersea Station

The National Oceanic and Atmospheric Administration (NOAA) launched in late 1987 the most advanced habitat ever developed for research under the sea. Named "Aquarius," the state-of-the-art, 81-ton habitat, which can sustain six scientists at a time indefinitely, has been placed on the Salt River Canyon seafloor off St. Croix, the U.S. Virgin Islands, the Commerce Department agency said.

For the next 2 years, the huge, moveable undersea research station missions will include fisheries studies, physical oceanography, marine engineering research, and studies of the cause of coral bleaching in the Caribbean. Aquarius makes it possible for scientists to live and work on the ocean floor for virtually unlimited time, allowing a 9-hour day of research before returning to the habitat. In contrast, scuba divers working at the Aquarius' present 50-foot depth would be able to remain on bottom for only 70 minutes.

The 43- × 12- × 16.5-foot station succeeds NOAA's smaller, less sophisticated habitat Hydrolab, which accomplished nearly 200 missions between 1966 and 1985. It was retired and presented to the Smithsonian Institution. Aquarius is divided into three compartments—a wet porch, main lock, and entrance lock. The main chamber houses the sleeping area, laboratory equipment, computers, environmental conditioning, and a modern galley. From the living compartment, scientists can view sea life through observation ports. A video system allows monitoring of seabottom and surface conditions.

Connected by an umbilical system to an unmanned surface support boat, the habitat functions independently of shore support. During any interruption of power or air, it can operate under an emergency system for up to 72 hours, allowing its occupants time to decompress and swim to the surface. The habi-

tat was towed on its separate launch, recovery, and transport (LRT) vehicle in September to Salt River Canyon, and lowered to the bottom from between the LRT's catamaran hulls to a moveable, 118-ton baseplate equipped with levelling legs. Built for NOAA at a cost of $5.5 million, Aquarius is being operated for its first one- to two-year deployment off St. Croix by the National Underseas Research Program of Fairleigh Dickinson University's West Indies Laboratory.

NOAA Unveils High-Tech Tsunami Warning System

The National Oceanic and Atmospheric Administration (NOAA) has announced the development of a high-tech tsunami warning system that could inexpensively safeguard millions of now-unprotected coastal dwellers. Tsunamis are walls of water pushed ashore by undersea earthquakes or volcanic eruptions. In the past 100 years, they have killed more than 51,000 people around the Pacific basin. A team led by the Commerce Department agency, using readily available technology and a NOAA weather satellite, has devised a system that protects Valparaiso, Chile, a Pacific coast city which has lost more than 1,500 persons to tsunamis since 1900.

Certain Pacific coastal areas are protected by a basin-wide network designed to warn nations of major, destructive events; five regional systems serve Hawaii, Alaska, Japan, French Polynesia, and the U.S.S.R. Pacific coast, according to Eddie N. Bernard of NOAA's Pacific Marine Environmental Laboratory (PMEL), who led the team. However, vast areas of Pacific coastline are not protected by the regional systems, which cost about $1 million to install and $500,000 a year to operate. The local-area Valparaiso system, in contrast, could be installed elsewhere for as little as $20,000. Bernard said coastal cities in Peru, Mexico, and the Caribbean are appropriate locations for similar systems.

Under sponsorship of the Agency for International Development's Office of Foreign Disaster Assistance, Bernard assembled a group of experts on seismology, oceanography, numerical modelling, and other specialties, to design, develop and evaluate a system that small nations could afford. Valparaiso was chosen for the pilot system because it already has a tsunami warning center, access to NOAA's GOES satellite, and was committed to improving its warning capabilities. The system had to be readily integrated into local warning capabilities, assembled mostly from existing technology, reliable, and capable of warning within 10 minutes. The system is designed to detect 7.0-scale undersea earthquakes 50 miles from shore, and 6.2-scale earthquakes 21 miles out. Most of the Valparaiso fatalities have been from tsunamis within 60 miles off the coast.

Key elements of the tsunami warning system are an accelerometer, a water level sensor, satellite communications, and pre-programmed computers. When an earthquake of 7.0 or more on the Richter scale occurs within 60 miles of the Valparaiso coast, the accelerometer is tripped, transmitting an alert through the GOES satellite. A computer simultaneously sends emergency messages to a warning center in Valparaiso, to the Pacific Tsunami Warning Center in Honolulu, and to water level sensors in Valparaiso Harbor. A computer in the city automatically warns public safety offices and begins monitoring the water level sensors. They, in turn, transmit tsunami wave information back through the satellite system. The warning system has yet to be tried under real conditions, when evacuation would occur, but in more than 5,000 tests done in the past year it has proved to be 98 percent reliable in warning transmission, and the equipment has performed with 94 percent reliability, Bernard said.

Five-Month Cruise Tabulates Dolphins

Two NOAA research vessels, the *David Starr Jordan* and the *McArthur*, returned to San Diego, Calif., on 10 December after spending almost 5 months at sea counting dolphins over a 5 million-square-mile area of the eastern tropical Pacific. The expedition was part of a 5-year dolphin study mandated by the U.S. Congress as a result of an amendment to the Marine Mammal Protection Act in 1984 to monitor the relative abundance of dolphin stocks in the eastern tropical Pacific. The NMFS Southwest Fisheries Center in La Jolla, Calif., is responsible for carrying out the program.

Logged into the computers aboard the ships during the long cruises is information obtained by a dozen scientific observers on numbers and kinds of whales and dolphins sighted, the species of sea birds seen such as sooty terns and brown-footed boobies that often accompany groups of dolphins and tuna schools, oceanographic measurements of currents, salinity, temperature, oxygen, weather observations, and other environmental data. This time, the NOAA Ship *Jordan* was also equipped with a helicopter and a helipad. The activity of the dolphin schools, which could number anywhere from 50 to 6,000 animals, was photographed from the helicopter with a special U.S. Navy camera designed for filming from high-speed, low-flying aircraft to provide better estimates of dolphin school size and composition.

The eastern tropical Pacific is the only area in the world where some schools of yellowfin tuna swim beneath dolphin herds. Tuna fishermen search for schools of dolphins with speedboats and encircle dolphins and tuna with huge nets. Although most of the dolphins escape or are released by fishermen over the nets, some animals unavoidably become entangled and drown. Last year more than 126,000 dolphins were accidentally killed in the eastern tropical Pacific by tuna fishermen from Ecuador, Mexico, Panama, the United States, Vanuatu, and Venezuela. Under Federal law, U.S. fishermen are limited to the accidental take of 20,500 of the mammals annually.

By the end of the 5 years, scientists will be able to compare data from each cruise and determine if stocks of dolphins in the eastern tropical Pacific are increasing or decreasing. If it is found that the mortality due to the tuna fishery has adversely affected the population of one or more dolphin stocks, the Secretary of Commerce is then responsible for taking action, as necessary, to modify the existing dolphin quotas for the U.S. tuna fishery to ensure that the dolphin populations are able to recover.

In addition to gathering information

about the numbers of dolphins in the eastern tropical Pacific, scientists from other agencies in NOAA and from the Tropical Ocean and Global Atmosphere (TOGA) Programme, an international program of which the United States is a member, are actively cooperating in this program.

Honolulu Lab Surveys Fish, Marine Mammals

Scientists of the NMFS Southwest Fisheries Center's, Honolulu Laboratory, aboard the NOAA ship *Townsend Cromwell*, completed a 9-day survey of marine mammals and deep-sea bottom fishes at Penguin Bank in the main Hawaiian Islands in November, according to Richard S. Shomura, Laboratory Director. Marine mammals, including porpoises and whales, are protected by Federal laws, and their occurrence and interaction with man is of considerable interest to scientists and local fishermen. Deep-sea bottom fishes, such as opakapaka, ehu, kalekale, and onaga, are of considerable importance to the local fishing industry and are heavily exploited.

Surveys were conducted by marine mammal scientists to determine occurrence, local distribution, and species composition of marine mammals at Penguin Bank, while bottom longline gear and deep-sea handline gear were fished in depths of 240-870 feet at four selected sites to determine the distribution, abundance, diet, and diel shifts of deepwater bottom fishes, according to Paul M. Shiota, Chief Scientist on the survey.

The marine mammal survey is part of a program at the Honolulu Laboratory to better manage and protect marine mammals in Hawaii. The deep-sea bottom fish survey is part of a cooperative study between the Honolulu Laboratory and the University of Hawaii. The information collected will prove useful in providing a better understanding of the diet, distribution, and abundance of commercially important bottom fishes at Penguin Bank.

Fish Export Data and Publications

The U.S. Department of Commerce has a new agency, totally separate from the International Trade Administration, which handles export licensing and control functions, the Department has announced. The Export Administration now is responsible for technology analysis, export enforcement, intelligence review, and anti-boycott compliance. The new Export Administration is located at the U.S. Department of Commerce/EA, Room 1099 HCHB, 14th and Constitution Avenue, N.W., Washington, DC 20230.

Also, if you are an exporter or broker and routinely file Shipper's Export Declarations, you may file these documents electronically, on a monthly basis, instead of filing a hard copy for every shipment. The Commerce Department's Census Bureau now has a National Clearinghouse for Exporter Data Processing. The Bureau can provide a brochure listing the service agencies in your city that have already registered with the Census Bureau. These agencies provide current listings of all commodity classifications, and transmit electronic data to the Bureau as part of their services to exporters. For more information, contact the U.S. Census Bureau's Automated Export Reporting Office at (301) 763-7774 or (301) 763-4040.

A marketing reference manual called "A Guide to Selling Your Service Overseas," which includes computer software products, is a clear and concise guidebook to selecting foreign markets. Copies of the 1987 issue of the Guide, are available from NORCALDEC (Northern California District Export Council) at $17.00 per copy (postage and handling included). Address orders to Service Guidebook, 450 Golden Gate Avenue, P.O. Box 36013, San Francisco, CA 94102.

The Census Bureau has also announced the availability of a new edition of Schedule B Statistical Classification of Domestic and Foreign Commodities exported from the United States, in which the export commodity classification system is converted to the nomenclature structure of the Harmonized Commodity Description and Coding System (Harmonized System). The commodity numbers contained in this revised Schedule B contain ten digits plus a check digit. They are to be reported on Shipper's Export Declarations beginning 1 January 1988. The metric system of weights and measures is used throughout the publication.

The 6-digit Harmonized System was developed from the Customs Cooperation Council Nomenclature and is intended for multinational use in classifying commodities in international trade. In Schedule B, it was expanded to ten digits plus a check digit for U.S. statistical needs. The structure and detail of this new system are significantly different from those previously in use.

The alphabetical index is contained in a separate volume and shows the first six digits of the applicable Schedule B code(s) for each commodity listed. This volume also contains correlations between 1987 and 1988 Schedule B numbers. The index and correlations are included in the price of the basic publication. You may order your 1988 edition of Schedule B (ask for order number 903-009-00000-4) from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402 (telephone 202-783-3238). The price is $46 ($11.50 additional for foreign mailing), and includes supplemental changes issued irregularly for an indefinite period.

Commercial Scallop Dredging Observed With Submersible

Commercial sea scallop fishing operations appear to: 1) Capture with high efficiency those scallops which are within the path of the scallop dredge, 2) cause very low mortality among those scallops which are within the path of the dredge but which are not captured by it, and 3) result in low mortality (i.e., less than 10 percent) of those scallops which are captured, but which are subsequently discarded.

These observations came from the NMFS Northeast Fisheries Center's 15-17 July 1987 study of commercial scalloping by the fishing vessels *Carolina Breeze* and *Mary Anne* in 175-220 feet of water in the Hudson Canyon area of the Middle Atlantic shelf. Center scientists used the two-man research submersible *Delta* to observe fishing operations directly.

The Fisheries of Chile

Chilean fish and shellfish landings decreased slightly during the first half of 1987, compared with the same period of 1986. Export shipments, however, increased over 35 percent by value during that same period. Frozen and fresh fishery products were the most rapidly growing exports. Fishmeal remained the most important fishery export commodity. New investments in the industry continue to be concentrated in salmon aquaculture. New Zealand investors, however, formed a partnership with a major company which may increase frozen fish production. The U.S. Embassy in Santiago, Chile has submitted the following report on recent Chilean fishery developments.

Landings Decline Slightly

Small Pelagics

Most of Chile's fishery landings are small pelagic species (sardines, anchovy, and jack mackerel) which are primarily reduced to fishmeal and oil. Chilean landings of these species declined during the first half of 1987 by about 10 percent from 1986 landings during the same period. Some observers suggest that the decline may be related to the 1986-87 El Niño which has affected Ecuadorean and Peruvian fisheries. It is unclear to what extent, however, the decline has resulted from El Niño, because the sea surface temperature anomalies associated with El Niño have been most severe off Ecuador and northern Peru and not off Chile[1]. Some observers believe that the declining catch may be at least partly caused by the heavy fishing effort directed at the country's small pelagic stocks during recent years. Some observers have expressed increasing concern about the level of fishing effort on Chile's small pelagic stocks. Government efforts to protect stocks may also adversely affect landings, at least in the short term. The Government closed the sardine fishery off northern Chile (Regions 1 and 2)[2] for 41 days in mid-1987. As a result, fishermen in these two northerly regions reported a 30 percent decline in landings during the first half of 1987. This trend was offset somewhat by improved jack mackerel catches reported off Talcahuano in southern Chile (Region 8); fishermen there reported a nearly 60 percent increase in their jack mackerel catch. The increase in Region 8 resulted from the decision by several companies to redeploy part of their fleet south to compensate for the closed season and declining sardine landings in Regions 1 and 2. During 1986, Chilean landings of both sardine and jack mackerel declined, but overall landings increased because of a massive increase in anchovy landings. Data on 1987 anchovy landings, however, are unavailable.

Other species

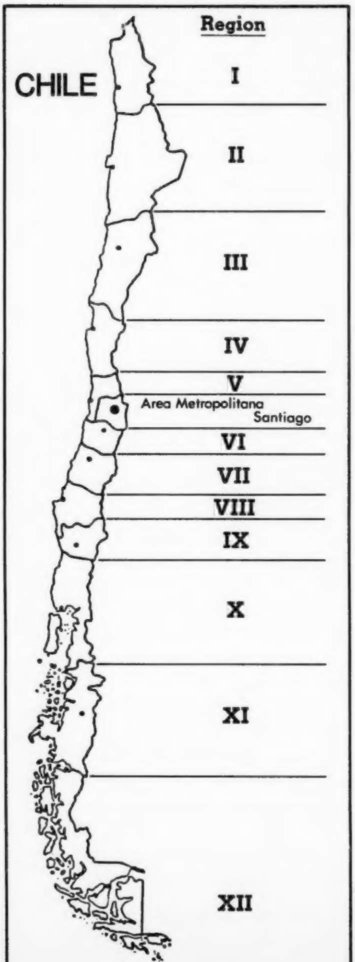
Artisanal fishermen land much smaller quantities of fish, but most of their landings are more valuable, and destined for human consumption. Artisanal landings during the first half of 1987 were 7 percent higher than those during the same 6 months of 1986. Chile has also developed an important seaweed industry in the past few years. The quantity gathered in 1986 declined, but gathering remained steady during early 1987.

Fishery Exports Increasing

Chilean fishery exports during the first 6 months of 1987 reached over $310 million, or 35 percent more than during the first 6 months of 1986 (Table 1). The increase was primarily caused by increased fishmeal prices, but important gains were also reported in other sectors. Data on 1985-86 exports are given in Table 2.

Fishmeal

Chile exported 616,000 metric tons (t) of fishmeal during the first 6 months of 1987, an increase of 20 percent over such shipments during January to June 1986. Exporters increased shipments during early 1987, despite declining landings. Exporters were able to achieve these increases by drawing on inventories to take advantage of rising world prices. As a result, the value of fishmeal exports increased 35 percent during the first 6 months of 1987. Chilean observers report



[1]Sea surface temperature anomalies off Ecuador and northern Peru were 3-4°C above normal during early 1987, but only 2°C above normal during March 1987, the peak of the anomalies off Chile. Water temperatures off Chile during the rest of the year have remained fairly constant.

[2]See map.

that if catches continue at current levels, full year 1987 fishmeal exports should equal 1986 levels in quantity, but earn more because of the increased prices.

Fresh and Frozen

Fresh and frozen fishery exports totaled 21,600 t during the first half of 1987, nearly a 60 percent increase over the 13,700 t exported in the same period in 1986. These exports grew over 100 percent (by value), to a total of $47.0 million compared to only $23.5 million. International prices for both fresh and frozen products have been strong, and Chilean exporters are predicting continued growth. A new partnership developed between Chilean and New Zealand investors, may contribute to an even more rapid growth in frozen and fresh fishery exports by the end of 1987.

Canned

Canned fishery exports increased 40 percent by both quantity and value during the first 6 months of 1987 to 16,100 t worth $12.4 million, compared to only 11,600 t worth $8.8 during the same period in 1986. Exporting companies reported that international prices for their product increased a moderate 1.4 percent. Shellfish exports (frozen and canned product) increased by 14 percent in value, while seaweed products increased by 10 percent. Other fishery exports, such as dried or salted fish, fish offal, fish by-products and unclassified fishery products, also increased in value terms, but landings were adversely affected by seasonal closures on several different species.

Table 1.—Chilean fisheries exports, January-June, 1986-87[1].

Product	Exports (USS million) 1986	1987
Fishmeal	138.0	186.3
Fish		
Frozen[2]	23.5	47.4
Canned	8.8	12.4
Shellfish	35.7	40.5
Seaweed	13.7	14.4
Other	10.3	10.9
Total	230.0	311.6

[1]Source: Indicators of Chilean Foreign Trade, Central Bank of Chile.
[2]May include small amounts of fresh product.

Table 2.—Chilean fisheries exports, 1985-86[1].

Product	Exports ($ US million) 1985	1986
Fishmeal	279.0	314.9
Fish		
Frozen[2]	47.8	67.2
Canned	10.7	26.0
Shellfish	57.9	76.6
Seaweed	23.7	23.2
Other	40.9	27.5
Total	460.0	535.4

[1]Source: Indicators of Chilean Foreign Trade, Central Bank of Chile.
[2]May include small amounts of fresh product.

Future Expansion

The most significant investment development during the first half of 1987 was the decision by New Zealand investor Carter Holt Harvey[3] (CHH) to purchase a 39 percent interest in a large Chilean fishmeal company, Pesquera Iquique. After investing $28 million, CHH became the partner of the largest Chilean fisheries industrialist, Anacleto Angelini, whose plants are responsible for some 40 percent of Chilean fishery exports. CHH is reportedly interested in expanding the company's operations which currently concentrate on fishmeal. CHH is particularly interested in increasing exports of fresh and frozen demersal fish. The CHH investment is the largest single foreign investment in Chilean fisheries.

The greatest foreign interest overall has been in Chile's booming culture of salmon in pens set along the southern coast. Production is primarily targeted for the U.S. market. Chilean farmers harvest their salmon during the northern hemisphere winter when prices in the United States are highest. Exports to the United States totaled $4.6 million during the first 6 months of 1987, compared to only $2.8 million during the same period of 1986. While still relatively small, some observers believe that salmon may eventually become one of Chile's principal fishery exports.

Comments

As international fishery prices continue to rise, Chilean fishery exports should continue to generate an important source of hard currency for the Chilean economy. Fishery exports remain Chile's third largest source of hard currency, after mining and agriculture. During the first 6 months of 1987, fishery commodities represented 13 percent of total Chilean exports, compared to 11 percent during the same period in 1986. Nevertheless, the continued strength of exports will be largely dependent upon the stability of Chilean landings. The status of major small pelagic stocks is not known, and several factors could significantly affect landings by the end of 1987. The Chilean Government may decide to further limit sardine and/or other small pelagic fisheries as a resource management measure. Heaving fishing effort could adversely affect stocks. The full impact of the 1986-87 El Niño event is still unknown. Each of these factors could have a serious effect on Chilean landings. The U.S. Embassy in Santiago reports that further government restrictions on landings would provoke loud protests from the Chilean fishing industry, an important source of political support for the current administration. The Chilean fisheries industry continues to increase its ability to compete efficiently in the international markets. The large New Zealand investment should help to further improve the competitive position of the Chilean fishing industry on world markets. (Source: IFR-87/71:DW.)

Additional Information

The U.S. Embassy in Santiago has prepared a 20-page report reviewing the status of Chile's fishing industry in 1986. The report includes sections on landings, fleet development, fisheries development, new fishery investment projects, ports, aquaculture, processing, markets, government policies, and research. The report has many appendices, including lists of fishery offices, trade associations and companies, and statistical tables on landings, processing, and fishery exports. U.S. companies can obtain a copy of "Chilean Industrial Outlook Report: Fishing Industry, 1986" for $9.95 and a $3.00 handling fee (total $12.95, personal checks or money orders only) by ordering report PB87-207692/GBA from NTIS, Springfield, VA 22161.

[3]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

The Fisheries of Southern Thailand

Major changes have swept through the southern Thai fishing industry during the past 2 years. Strict enforcement of Exclusive Economic Zones (EEZ's) by neighboring Burma, Malaysia, and Vietnam, has nearly eliminated alleged Thai poaching in these waters. Malaysian arrests of Thai fishermen have touched off protest demonstrations in Songkhla and Pattani ports on the southeastern coast of Thailand, while a Burmese fisheries enforcement program using a Japanese-donated fleet of 42 patrol boats and 6 helicopters has crippled Ranong, formerly a port of choice on the Andaman Sea.

The EEZ squeeze has sparked an internal migration of the Thai fishermen from central provinces to the south, and from the east to the west coast, in order to gain better access to international waters. Smaller trawlers continue to fish in national waters of the Gulf of Thailand where fishery resources are rapidly declining. But larger trawlers and more sophisticated purse seiners, equipped with sonar and night-fishing gear, are ranging further afield into the international waters of the South China and Andaman Seas. Both trawler and purse-seiner fishermen have greatly benefited from two important trends. The falling diesel fuel price has reduced costs and rising fish prices have increased profits. Fish prices are 20-30 percent higher than during 1985, a result of more sophisticated processing and international marketing.

While overall catches are slightly lower, fishermen interviewed in nine southern Thai ports expressed satisfaction with current conditions—the "Year of the Golden Sea", according to one—and are optimistic about the future. Government efforts are geared to internationalize the fleet by sponsoring joint-venture agreements with other nations, and modernizing fishing vessel design and fishing methods to allow for more extended fishing trips. To this end, the Government recently opened the Tinsulanonda Songkhla Fishery College. The college, Thailand's first, will educate a new generation of deepsea fishermen and introduce new vessel designs, fish processing techniques, and capture methods.

Background

Thailand's rise to its position as Southeast Asia's preeminent fishing nation began with the introduction of a seagoing trawler in the early 1960's. Designed by the Thai Department of Fisheries and constructed at local shipyards with indigenous wood, the trawler was powered by a large inboard diesel, furnished with ice-storage space and equipped with winch and crane apparatus for hauling in large catches. The modern vessel was a revelation for Thai fishermen. The Thai fleet mushroomed from only 99 vessels in 1961 to 5,200 in 1974, and approximately 9,000 today. The land-based infrastructure, necessary for an export-oriented fishing industry, developed in tandem with the Thai fleet: Coastal roads, refrigerated trucks, shipyards, ice plants, fish meal factories, cold storage plants, and canneries.

The industry, however, fell victim to its own success. Throughout the 1970's, neighboring countries proclaimed 200-mile EEZ's off their coasts, barring Thai trawlers from some 110,000 square miles of fishing grounds—half the area once exploited. Though some captains continued to fish in those waters, risking arrest and confiscation of their vessels, those content to remain in safe waters may have overfished the Gulf of Thailand. Industrial pollution and dynamiting of coral reefs has further reduced the catch along the central provinces. All told, the average catch dropped from 298 kg per hour in 1961 to a mere 47 kg in 1975. The Thai fishing fleet was also crippled, between 1972 and 1978, by a tenfold rise in the diesel fuel price—an expense which reportedly accounts for 65 percent of a trawler's operating costs.

The fortunes of the Thai fishing fleet bottomed out in 1980 when the annual catch declined by 20 percent below the 1977 record of over 2 million tons. The stabilization, and then fall, of the diesel price allowed the fishing industry to rebound. While the 1986 catch is expected to decline slightly, prices are up 20-30 percent. Besides the fuel and fish price fluctuations, improved fishing, processing, and marketing techniques have all played a role in the relatively healthy state of southern Thai fisheries. Personnel of the U.S. Consulate in Songkhla visited 10 southern Thai fishing ports in 1986, and submitted the following report which documents the ingenuity of Thai fishermen in coping with contemporary problems.

Ports and Production

In general, the northern and northeastern Thai ports are faring poorly; the southern ports, with easy access to international waters, are booming. The 10 southern ports described in this report are important because the entire marine catch of this reigon is landed there. Chumphon, the northernmost port in the southern half of Thailand, has fared poorly since its approach channel began silting up. In 1986, some 40 of its 422 trawlers left for more southern ports. Fishing in Vietnamese waters has long been too risky and fishermen are also prohibited from trawling closer than 3,000 m to islands offshore from Chumphon and Surat Thani provinces (in order to preserve islanders' traditional fishing grounds). Thai Navy and Marine Police Patrols strictly enforce this law.

Despite such restrictions, 138,000 metric tons (t) of fish, valued at over \$42.3 million, were landed on Chumphon docks in 1985—a nearly twofold increase over its 1980 low. Chumphon's attractions are it's relative proximity to Bangkok and a good fish

market. A prosperous province, Chumphon also has much ready capital for infrastructure investments. To date, it has constructed 3 canneries, 7 fish-sauce plants, 8 fishmeal plants, 13 ice factories and 5 cold stores. Chumphon, however, bears the dubious distinction of being the only province where fishermen must contend with piracy. A captain and his crew were wounded in 1986 during a robbery attempt. Extensive use of inter-fleet and ship-to-shore radios, however, have helped to eliminate a once-common scourge in southern Thailand.

Surat Thani, 90 miles to the south, is also in serious decline as a fishing port. Not only is its channel silting up, but large rocks at the entrance makes approach in low tides increasingly dangerous. With delays at the channel mouth common, some 80 percent of the larger trawlers have abandoned Surat Thani for Khanom, 40 miles east in Nakhon Si Thammarat Province, where passage, docking space, and ice are plentiful. The catch landed in Surat Thani fell from 125,000 t in 1984 to 118,000 t in 1985; catch estimates for 1986 are much lower. Infrastructure is also less developed than at Chumphon: only 2 canneries, 3 fish-sauce factories, 4 fishmeal plants, 8 ice factories, and 3 cold stores.

While the Government-owned fish marketing organization in Surat Thani reports a drastic decline in trawler landings, canneries and similar plants have, as yet, suffered no shortage of material. Truck convoys carrying iced fish from Khanom keep them regularly supplied. Surat Thani's harbor problems could be solved by relocating the fish market to its new port, outside the old channel. To date, however, provincial authorities have balked at the idea, preferring to receive high rents from private companies rather than give space to state enterprises. The alternative solution—demolition of the rocks in the estuary—would not be cheap: It would cost over $6 million.

Khanom, now the premier fishing port in Nakhon Si Thammarat Province, has boomed since 1983 when Electrical Generating Authority of Thailand (EGAT) opened a major hydroelectric plant and deep-dredged its harbor channel. Private docks, ice factories, and cold stores quickly sprang up and triggered a fishing boom as trawlers from Chumphon and Surat Thani flocked to take advantage of Khanom's speedy offloading facilities. The province's fish catch, steady at around 52,000 t between 1980-1984, increased more than fivefold to 278,000 t in 1985, valued at $14 million.

In contrast, Pak Phanang, Nakhon Si Thammarat's traditional port some 70 miles south of Khanom, has fallen on hard times. As in Chumphon and Surat Thani, its harbor is silting up, driving a third of the trawler fleet south to Songkhla. There are other special problems and fishermen prefer to offload in other ports where prices are freer and higher. By the end of 1987, however, a partial solution may be at hand. The state-owned Fish Marketing Organization will construct a dock and cold storage facility costing about $3.5 million, financed by a Japanese loan. This, in turn, may loosen the local grip on marketing, though there is doubt that Pak Phanang will regain its former status.

Songkhla has long been southern Thailands' largest fishing port. Until 1985, it landed twice as much as the next two ports, Kantang and Pattani, combined. Songkhla's infrastructure is also the most developed, with 11 canneries, 20 ice factories, 5 fishmeal plants, and 2 cold stores. In 1984, the fisheries catch stood at 442,000 t, valued at $71.2 million. In 1985, however, production plummeted to 165,412 t valued at $27.8 million. This 63 percent decline reflects, in part, the desertion of a sizable purse seiner fleet to Pattani. For the six previous years, fishing vessels had been migrating from the depleted fishing grounds of central provinces (like Samut Sakhon) to take advantage of Songkhla's proximity to international waters.

Songkhla's very success proved its bane as the press of boat traffic placed impossible demands on its dock space. Trawlers also have had to put up with long queues for ice, water, and fuel. Offloading is similarly time-consuming as the Fish Marketing Organization's pier is too small for current volume. A municipal fishing port, scheduled for completion in 1990 (at at cost of $9.6 million, 60 percent of which is provided by an Asian Development Bank ADB loan), will ultimately relieve congestion. Marketing problems, however, remain unsolved. Songkhla's tough fish brokers have consistently paid less for the catch than buyers in neighboring Pattani. Prices in Pattani, in fact, average one baht (about $0.04) higher per kilo—strong incentive for migration.

Pattani is the fastest growing fishing port on the southeastern coast. Fifty miles south of Songkhla, and even closer to international waters, it has attracted a large fleet from other provinces. This fleet is also southern Thailand's most sophisticated: it comprises 200 sonar-equipped purse seiners and 250 trawlers (70 percent of which are over 50 t). All vessels being built in Pattani shipyards are purse seiners, while many large trawlers (70 to 100 t) are being converted for seining, a process spurred by ADB small loans to fishermen for sonar gear and purse seine nets. Purse seiners and large trawlers fish mainly in the international waters of the South China Sea. A promising Thai-Indonesian joint venture has been launched with 3 purse seiners. As Pattani's fleet has burgeoned, so has its infrastructure: 11 ice factories, 3 cold stores, 4 fishmeal plants, and 2 canneries. Pattani's fish market is freewheeling,

backed by a healthy cross-border trade with Malaysia. Each day about 100 pickup trucks deliver fish to customers in Malaysia and 30 ten-wheel trucks deliver to Bangkok.

Ranong, on the west coast facing Burma, is having hard times. Once southern Thailand's largest fishing port, Ranong's catch has shrunk from 110,000 t in 1977 to 68,000 in 1985. In 1986, it is estimated to have plunged another 40 percent, as the Burmese drastically increased surveillance of their EEZ following the establishment of a joint-venture with the Japanese. A Japanese firm, Nikata, has provided the Burmese with training, technology, equipment, and cold stores. Some fish are sold in Burma, but better quality marine products are processed and sold to Japan. To protect their investment, the Japanese have provided the Burmese with 42 patrol boats and 6 helicopters to discourage poaching. Thirty Thai boats were seized in 1985, 10 in 1986. Arrested Thai crewmen are now jailed for 4 years, captains for 7 years. In response, over 100 of Ranong's 277 trawlers have fled south to Phuket. Another 100 purse seiners, which once migrated to Ranong during the December-March east coast monsoon, now favor Phuket and Kantang. Limited poaching persists during the west coast's 4-month rainy season (June through September), when the Burmese refuse to brave the high seas. Ranong's infrastructure remains small at 8 fishmeal plants and ice factories, and no canneries. Most fish is sent to Bangkok, but some is also delivered to Hat Yai for export to Malaysia.

Phuket, located 140 miles south, has profited from Ranong's misfortune. Most of Ranong's trawlers now offload their fish in Phuket, and 100 purse seiners from Pattani and Songkhla call there from December to June. The increased traffic has strained Phuket's ice plants, and additional supplies are occasionally trucked from Phang Nga to make up the shortfall. Phuket's infrastructure remains primitive with 6 ice factories, 3 fishmeal plants and 1 cannery. In 1984, Phuket's domestic catch was 41,500 t, plus another 9,800 t from a joint venture with Indonesia. Nine large trawlers were involved in the joint venture. Fishermen found, however, that catches were low and profits meager, and only a single trawler now makes monthly trips to Indonesia. A de facto Thai-Burmese joint venture has evolved, whereby the Burmese sell their catch to the Thai on the high seas (done at Kantang and Satun as well). A more official joint venture has been initiated with Bangladesh: Thai trawlers land large fish there, and small fish in Phuket. In 1985, Phuket's domestic catch increased to 56,200 t, and is expected to be substantially higher in 1986. About 40 percent of the catch is trucked to Hat Yai for sale in Malaysia; the rest is trucked to Bangkok.

Kantang, 100 miles south of Phuket, is the west coast's largest fishing port and, until the dramatic rise of Pattani, southern Thailand's second largest fish producer. Its main dock, belonging to the municipality, services some 100 trawlers. Another 240 trawlers dock privately. Kantang's fisheries infrastructure consists of 8 ice factories, 4 fishmeal plants, 2 cold stores, and a cannery. Kantang has abundant dock space, fuel, and ice supplies. A thriving shipyard industry specializes in the construction of large purse seiners, wide-beamed for greater ice storage and capable of staying at sea for over a month rather than the usual 15 days. (These large seiners no longer expend fuel for biweekly return trips, but rely on small boats to transfer the catch back to Kantang). The Kantang fleet also runs on cheap Malaysian diesel fuel, giving a hefty boost to profit margins. Although vessels fish mainly in international waters, a few may poach in Indonesian waters. None fish in Malaysian waters since the arrest of a crew last year. Roughly half of Kantang's fish catch is trucked to Hat Yai, and from there to Malaysia. Some 137,000 t were landed in 1984, and 133,254 t in 1985. The 1986 catch is expected to be about the same, but, with prices running 30 percent higher, profits will be huge.

Satun, near the Malaysian border, is also prospering, as its catch rose from 69,000 t in 1984 to 74,000 t in 1985. The port is equipped with 5 ice factories, 2 fishmeal plants, 3 cold stores, and a cannery. Satun's proximity to Malaysia has allowed a cross-border arrangement whereby Malaysians secure part ownership of Thai trawlers and register them in Malaysia. (These owners do not appear on Thai registers, so as to avoid Thai taxes). Such jointly owned boats, crewed by Thais, then fish with impunity in Malaysian waters. None has been arrested in 2 years. Trawlers secure cheap diesel fuel in Malaysia and sell their large fish there at high prices. Smaller fish are offloaded in Satun.

Fishery Exports

Thailand's exports have boomed. Rising international demand has pushed up prices, while 1985's baht devaluation and a high sales volume have allowed Thai firms to offer extremely competitive prices. Ever more sophisticated freezing and canning facilities, catering to the high quality standards of importing countries, further guarantee sales. Marine exports fall into four main categories: 1) Frozen shrimp, 2) frozen cephalopods (squid, cuttlefish and octopus), 3) fishmeal, and 4) canned seafood.

Thailand's most important marine export is frozen shrimp. Exports have climbed steadily since 1980 when they stood at 18,000 t with a value of $99 million. In 1986, frozen shrimp exports were expected to reach a record 29,000 t valued at nearly $162 million. Japan generally accounts for half the shrimp market, and will likely buy more this year because of the strong yen and increased consumer confidence in the quality of Thai shrimp. The United States, Thailand's second largest customer, along with other buyers—Singapore, Hong Kong, the United Kingdom, the Federal Republic of Germany, Italy, and France—have also been placing larger orders for frozen shrimp, pushing up prices. Further strengthening Thailand's marketing position has been the decline of its competitors (Taiwan, India, and Pakistan) all of whom report dwindling shrimp catches.

Squid and cuttlefish, are still abundant in Thai waters. As heavy fishing adversely affects stocks of fish predators, cephalopod stocks have increased. Japan and Italy are the top buyers of these frozen products, each accounting for 40 percent of the market. During the first 5 months of 1986, Thailand exported 19,000 t of frozen squid, cuttlefish, and octopus, valued at $45.8 million, an in-

crease of 14 percent by quantity and 62 percent by value over 1985. In the past, Italy has temporarily banned Thai squid imports for poor quality, causing prices to plunge. But Thai exporters seem to have greatly improved quality standards and Italian consumer confidence in Thai squid has stabilized.

Long plagued with a sluggish market, the fishmeal industry remains in the doldrums. Used primarily as livestock fodder, fishmeal is manufactured from trash fish, which represent 60 percent of fishery landings. With some two-thirds of Thai fishmeal production located in the south, the health of the industry has a profound impact on the region. Between 1984-1985, fishmeal production fell by 2,000 t to 183,000 t. Weak demand by the local livestock industry and competition from soybean meal also caused domestic prices to drop. In January-June 1986, overseas sales of fishmeal totaled 38,407 t, valued at $12 million. Stiff competition from Peru and Chile, where the catch of pelagic species, used for reduction to fishmeal, has been increasing, is further hampering fishmeal exports. Both countries reportedly offer fishmeal of superior quality at cheaper prices.

Thailand's newest, fastest growing marine export sector is canned seafood. The industry dates only to 1974, when Thai canneries exported a mere 474 t. Four years later, exports had risen to 13,000 t, and by 1982 had increased nearly fivefold to 66,000 t. By 1984, canned seafood exports had grown another 20 percent to 82,000 t. Reflecting this growth, the number of canneries has increased from 30 to 50 percent over the past 2 years; one-third are located in the south. Exports amount to 80 percent of production. Of the total exported, 55 percent is canned fish, and 40 percent is canned shrimp, crabmeat, and clams. The United States is the largest market, followed by West Germany, Britain, Canada, and Australia. Particularly significant are tuna exports to the United States, the value of which doubled in 1985. In 1984, American tuna processors asked the U.S. International Trade Commission to impose a 35 percent tariff on Thai tuna. That request was turned down, but American and Thai cannery groups are preparing for another legal battle.

Official promotion of Thai fisheries has centered on joint fishing ventures with neighboring countries, whose ever stricter enforcement of EEZ's has cost the Thai fleet dearly. (In 1985, a total of 86 Thai trawlers with 1,246 crewmen was seized in foreign territorial waters: 38 off Vietnam, 28 off Malaysia, 14 off Burma, 4 off Indonesia, and 2 off India.) In the summers of 1985 and 1986, tension between Thai and Malaysian fishing interests ran high, leading to one clash on the high seas, numerous arrests, and prolonged protests at the Malaysian Consulate General in Songkhla. Subsequent, high-level discussions in Bangkok and Kuala Lumpur, however, settled immediate differences.

More recently, in November 1986, Burmese patrols seized 9 Thai trawlers and arrested 300 crewmen. To avoid future conflicts and provide fishery grounds for its huge fleet, the Thai Government has worked to arrange joint fishing ventures with Malaysia, Indonesia, Bangladesh, India, Saudi Arabia, Oman, China, and Australia. Full accord with Malaysia has yet to be worked out, largely because of strong opposition by east coast Malay fishermen. A modus vivendi, however, appears to be developing, whereby Thai trawlers headed for international waters are allowed free passage, while those trespassing too close inshore (and fishing as they head south) are liable to be arrested.

In October 1986, the Thais succeeded in signing several joint fishery ventures with India and Indonesia, the latter involving an initial fleet of 60 trawlers. That same month, the first 3 Thai trawlers arrived in Darwin to open the initial phase of a joint venture with Australia. As its fleet expands globally, Thailand hopes that it will evolve into an international enterprise akin to the Japanese and Korean fleets.

Official assistance has also come in the form of aquaculture projects, which are located in all of the 14 southern provinces. In 1981, the Thai Government opened the National Institute of Coastal Aquaculture in Songkhla and, in 1985, the Brackish Water Research Institute in Surat Thani. Besides conducting extensive research, both institutes provide seedstock and technical assistance for the raising of sea bass, red snapper, Nile tilapia, oysters, clams, and prawns. On the west coast, Phuket, Trang, and Krabi have taken the lead in developing aquaculture in mangrove areas. The fishery department has also heavily promoted freshwater aquaculture projects in inland districts. Freshwater fish production, however, continues to be less than a tenth of marine production.

The most recent development has been the opening of Thailand's first fishery college in September 1986. Located in Prime Minister Prem's home town of Songkhla (and bearing his family name), the project is well-funded and off to a good start. An initial student body of 502 and a faculty of 34 is slated to grow within 5 years to 840 and 70, respectively. Building construction is nearly complete on a 120-acre site, with another 120 acres held in reserve for future expansion. Facilities include classrooms, laboratories, lecture theaters, workshops, processing and freezer rooms, brackish water and freshwater hatcheries, and a fish food preparation building. Foreign assistance is being provided by British experts attached to the British Council and by the Danish Government, which is providing a team of technicians and a modern freezer-equipped trawler.

Three-year course requirements include general fisheries, product preservation, aquacultural engineering, fish processing, capture methods and equipment, fishery physics, boat engineering, radio communications, navigation, fish, prawn and crab culture, and fishery marketing. Students include many sons of trawler owners who can be expected to bring their expertise back to family enterprises. Others will develop aquaculture on family coastal and inland plots. The Government also plans to recruit from the student body a cadre of trained specialists to expand its network of fishery projects. One likely by-product of the college will be improved technology for the post-harvest care of the catch. On average, a third is lost through spoilage. Looking ahead, improved technology and better preservation methods will work to extend the present range of the Thai fleet, and improve its ability to fish in international waters less fettered by EEZ's. (Source: IFR-87/23:BB/PN.)

Fisheries Research and Developments in Asia

"The First Asian Fisheries Forum," has been published by the Asian Fisheries Society, MC P.O. Box 1501, Makati, Metro Manila, Philippines, and was edited by J. L. Maclean, L. B. Dizon, and L. V. Hosillos. The Forum, held in 1984 in the Philippines, highlighted important regional fisheries developments in the last 40 years, and was large. The volume produced is also large, at 727 pages, but it well reflects the vast range of interests in the realm of Asia's marine fisheries.

The fisheries of Asia are important in and outside the region: Four of the top ten fish producing nations of the world are there; so are seven of the top ten shrimp producing nations. Fisheries research, as reflected in this huge volume, will no doubt help the industry to develop and grow.

At the Forum, some 230 papers were presented, with some eventually published elsewhere, others withdrawn or not considered, and the remaining 167 papers are published here. It begins with three Plenary Reviews: An overview of the fisheries and aquaculture industries in Asia by Chua Thia-Eng; new developments in fish nutrition by Akio Kanazawa; and concepts that work: Some advances in tropical fisheries research by Daniel Pauly.

The remainder of the contributions are divided into eight sessions: Aquaculture Systems, Biochemistry, Biology, (developmental and general); Fish Health, Pollution and Toxicity (subdivided into bacterial diseases, parasites, pollution, toxicity, viruses, and general studies categories); Fisheries (subdivided into development and management, education, gear and methods, information, postharvest and marketing, and resource assessment categories); Nutrition and Feeding Habits; Physiology; and Reproduction.

The first thing that strikes the reader is the breadth of scope of the contributions and the number of them. It makes an impressive reference which is priced in an effort to be available to many scientists in that part of the world. Many of the papers deal with tilapia and tilapia culture. Many others discuss various Asian shrimps and their culture, and problems associated with fish culture. Other articles describe methods developed for culturing tridacnid clams from seed size to maturity in a natural environment; milkfish, seabass, and oyster culture; and more.

More specific biological studies include gill development in the cichlid *Oreochromis niloticus*; early development stages of the red sea bream; ecology and biology of giant mantis shrimp; growth performance indices of 100 tilapia populations; feeding ecology of *Penaeus monodon*; biology and culture of *Ranina ranina* Linnaeus (variously called the spanner, frog, or kona crab); and a report on ichthyoplankton studies in the southern Java Sea.

The "Fish Health" section includes seven studies on bacterial diseases and five on pollution problems and its effects on various species; there are eight papers on parasite studies, including reviews of parasites of juvenile milkfish, parasites of the Nile tilapia in the Philippines; the

Finding Environmental Data for the Chesapeake Bay

Publication of bibliographies and data sets seems to be waning, at least in part due to cost factors and the hope that such items will be found in database searches, etc. Too often, though, many materials are unused or at least underutilized, especially if not published or referenced in the formal literature. To remedy that situation for the Chesapeake Bay region, the University of Maryland Sea Grant College Program has published the **"Chesapeake Bay Environmental Data Directory,"** compiled by Dan Jacobs, Daniel Haberman, David Smith, David Swartz, Elizabeth Sigel, and Michael Adams, as a cooperative project with NOAA and the Virginia Sea Grant College Program.

As Jacobs points out, much of that data is constantly collected through environmental satellites, oceanographic ships, weather stations, scientific studies, and management monitoring efforts, but locating specific data is both difficult and costly. Says Jacobs, "Potentially valuable data sets have gone unused because their existence is not widely known, they are poorly documented, or they are difficult to obtain." This new book, though, documents 826 sources of Chesapeake Bay environmental data, tells how and when they were collected, as well as information on usage limitations, data quality, and where they are available. It contains 2,242 entries, a principle investigator and contact organization index, and a key word index.

Each summary provides enough information so researchers can decide whether a data set is relevant to a specific need. Data may be stored on paper, magnetic media, microfiche, charts, graphs, or maps, and as much information as possible is given about availability, charges, and restrictions (if any) on use of the data. Included is data on fishes, water temperatures, currents, aquatic ecology, water quality, and much more. The 926-page volume is paperbound, costs $10, and is available from the University of Maryland Sea Grant Program, 1224 H.J. Patterson Hall, College Park, MD 20742.

parasite fauna of seabass, *Lates calcarifer*, in Malaysia and Thailand; and a brief review of toxic dinoflagellates in Japan, along with other papers on toxicity studies, viral studies, etc.

The theme of the Forum was "Traditional Practices and New Frontiers in Asian Fisheries," and the volume reflects that with papers on both current harvest and farming techniques and the latest developments in Asian fisheries research. The 727-page hardbound book has species and author indexes and lists Forum participants. Cost is US$40 (surface mail), US$60 (airmail in Asia), and US$64 (airmail elsewhere).

LIVES OF THE DINOFLAGELLATES

F. J. R. Taylor of the University of British Columbia has edited the new, large, and thorough Botanical Monograph 21 entitled **"The Biology of Dinoflagellates,"** which has been published by Blackwell Scientific Publications, Inc., 667 Lytton Avenue, Palo Alto, CA 94301. Claimed by both botanists and zoologists (as algae and protozoans, respectively), and with their nomenclature regulated by both the International Code of Botanical Nomenlaclature and the International Code of Zoological Nomenclature, the dinoflagellates are an interesting group for study. They also have a long fossil record of about 220 million years and, unfortunately, a few of them are highly toxic, and can make certain fishes very hazardous to eat (see Mar. Fish. Rev. 48(4):1-59).

This new volume, authored by internationally recognized authorities, provides a comprehensive review of the biology and ecology of this group which will be an important reference work on them. About 2,000 living species and 2,000 fossil species had been described by the late 1970's and perhaps about half the living ones are photosynthetic. To avoid the "animal or plant" controversy, they may be referred to as "protists," unicellular eukaryotic organisms.

Taylor himself provides an introductory chapter on general group characteristics, special features of interest (such as toxicity, luminescence, etc.), and a history of dinoflagellate studies, as well as the chapter on dinoflagellate morphology. John D. Dodge then reviews general ultrastructure, updating his own 1971 work, while C. Greuet reviews the complex organelles. Peter J. Rizzo then reviews the biochemical properties of the dinoflagellate nucleus and Barbara Prezelin discusses the photosynthetic apparatus and physiology of dinoflagellates.

About half the dinoflagellates are obligate heterotrophs, and Gregory Gaines and Malte Elbrachter discuss heterotrophic nutrition—types of heterotrophy, symbiosis, feeding organelles, and apochlorosis. Bioluminescence and circadian rhythms are reviewed by Beatrice M. Sweeney in Chapter 7 and then Yuzuru Shimizu presents a thorough discussion of the toxins of *Gonyaulax*, *Gymnodinium breve*, *Gambierdiscus toxicus*, and those of other species. Dinoflagellate sterols are outlined by Nancy Withers while M. Levandowsky and Pamela J. Kaneta discuss dinoflagellate behavior.

Taylor then reviews general considerations on the ecology of dinoflagellates and discusses their ecology in marine ecosystems, while Utsa Pollingher reviews their ecology in freshwater ecosystems. Additional chapters discuss parasitic dinoflagellates, dinoflagellates in nonparasitic symbioses, dinoflagellate reproduction, and dinoflagellate cysts in ancient and modern sediments. An appendix is also provided by Taylor on taxonomy, along with an outline classification of the living dinoflagellates. Each chapter carries extensive references, and the book has taxonomic and subject indexes. Hardbound, the 785-page volume is an impressive reference and is available from the publisher at $180.00.

How to Write and Present Technical Data

"The Basics of Technical Communicating" by B. Edward Cain, an ACS Professional Reference Book, has been published by the American Chemical Society, 1155 Sixteenth Street, N.W., Washington, DC 20036, and it provides good and sound information for the scientist/writer.

The book is divided into three parts. Part one on "Improving your technical communication skills," has an introductory chapter defining just what "technical communication" is. Chapter 2 quickly gets to the meat of the topic, specifically detailing how writers can eliminate wordiness and jargon and presenting appendices of all-to-common phrases with unnecessary words, phrases which can (and should) be replaced by shorter words, tautologies, and "absolute" words that resist (or simply do not need) modifiers, such as "dead," "extinct," "rare," "vertical," and others. Chapter 3 reviews correct punctuation and chapter 4 makes some good points on selecting and using appropriate verbs.

Part 2, "Assembling your report," leads prospective communicators through outlining, gathering data, documenting (with footnotes, endnotes, and bibliographies), abstract preparation, and proofreading (recommending that the author read the proofs and a colleague read the paper). Chapter 10 provides suggestions on using computers and word processors to their best advantage. The author even recommends "the old fashioned art of making notes" instead of wholesale photocopying of a source (which may indeed be illegal).

The chapter on visual aids and graphic art is also excellent, pointing out common pitfalls and showing authors how to present their data clearly and simply. Discussed are charts, diagrams, graphs, tables, and photographs, and the author warns against "chartjunk" or cluttering up visual aids with unnecessary gimmicks or shadings.

Part 3 addresses the scientist's "Specific Needs," beginning with directions for preparing academic laboratory reports, industrial and business reports, grants, and proposals, and even business correspondence, resumes, memos, and short reports. Chapter 14, "Journal Publication" provides useful advice for those wanting to publish a paper, ranging from deciding where to seek publication, what type of communication to submit (article, note, review, letter, etc.), determining the proper format, organizing the mate-

rial, and then explaining the review process for the prospective author.

Communicating scientific thought and progress is not always easy, but this book should help smooth the road for potential authors. It presents important information in a clear, easy-to-read, straightforward manner. The 198-page volume costs $29.95 (hardbound) in the U.S. and Canada and $35.95 elsewhere; paperbound copies cost $19.94 in the U.S. and Canada and $23.95 elsewhere and is sold by the ACS Distribution Office, Dept. 390 (address as above).

Also published by the ACS is "Writing the Laboratory Notebook" by Howard M. Kanare which presents basic data on creating a proper record of their work studies and explains the role that a notebook should play in experiment planning, observation, and analysis of data.

Progress, Problems, and Potential in Aquaculture

Review papers from the World Conference on Aquaculture, held in Venice, Italy, in 1981 have been published as **"Realism in Aquaculture: Achievements, Constraints, Perspectives"** (edited by Martin Bilio, Harald Rosenthal, and Carl J. Sindermann) by the European Aquaculture Society, Prinses Elisabethlaan 69, B-8401 Bredene, Belgium. Most of the articles are reviews of the results of scientific research, though some summarize and evaluate practical experiences and public regulations, and others assess the potential for future aquaculture developments. And in sum, the papers do a fine job of addressing the rationale of the conference—to evaluate as comprehensively and effectively as possible aquaculture research efforts, developmental trends, and commercial realization.

The keynote lecture, by O. Kinne, presents the views of a well-known ecologist on food production, ecological and other limitations on aquaculture, and his outlook on the future of aquaculture. That is followed by articles on the current status of aquaculture and developments in Japan and the Mediterranean region. In addition, recent advances in the culture of molluscs and crustaceans, seaweed culture, and the use and production of microalgae as a food in aquaculture are presented. Other articles discuss brine shrimp and other organisms as foods in aquaculture programs, aquaculture nutrition, control of fish reproduction, mass rearing of fish fry, species transfers and introductions and the problems involved, the role of pathology in aquaculture, genetic factors in aquaculture, and stress and behavior in the culture environment. Additional papers are presented on culture system design and water quality criteria, application of aquaculture technology, economic aspects of aquaculture, pertinent legislation and regulations in various nations, and product quality criteria and quality control.

Unfortunately the volume is not indexed, for it presents some very good and authoritative reviews of important aquaculture topics. The 585-page paperbound volume is available from the Society (price not listed).

The Society's Special Publication 9 is **"Pathology in Marine Aquaculture,"** edited by C. P. Vivares, J. R. Bonami, and E. Jaspers, and it constitutes the Proceedings of the First International Colloquium on Pathology in Marine Aquaculture held in 1984 in Montpellier, France.

The Proceedings is published in five parts: 1) Ecopathology (with articles on epidemiology, the influence of environmental factors on certain diseases, and the parasitofauna of the hosts), 2) Parasitic diseases (those maladies caused by protozoans, helminths, and crustaceans), 3) Infectious diseases (with papers on fungal, bacterial, and viral diseases), 4) Tumors, and 5) Immunology, Prophylaxis, and Therapy. A number of the papers are in French, but all include abstracts in both French and English.

Some papers of interest include a case history of the *Bonamia ostreae* control in the Dutch oyster culture, a summary and analysis of epidemiological knowledge on bivalve mollusks, a review of problems involved in research on protozoan parasites of marine fishes, aspects of the feeding behavior of *Carcinonemertes errans* (an egg predator of the dungeness crab), histopathological effects of certain coccidia infesting certain Mediterranean fishes, viral infections in the crab *Carcinus mediterraneus*, and molecular biology of fish lymphocystis disease virus. Others relate aspects of ecology and histochemistry of rodlet cells of teleosts, review bacterial problems in oysters, review fungal diseases in marine invertebrates, and discuss organ distribution and morphology of antibody producing cells in *Sebastiscus marmoratus*, examples of neoplasia or neoplastic-like conditions in marine fishes from the Registry of Pathology at the Fish Diseases Laboratory in Weymouth, and more. The 428-page paperbound volume is available from the Society (price not listed).

The Design and Use of Small-Scale Fishing Gear

The second edition of the FAO's **"Catalogue of Small-Scale Fishing Gear"** has been released by Fishing News Books Ltd., 1 Long Garden Walk, Farnham, Surrey, England, GU9 7HX. The book is edited by C. Nedelec, and was revised and enlarged by J. Prado. In format it is like the first edition, consisting primarily of gear designs and specifications, and indicating the uses of each pattern. The few pages of text are published in parallel in English, French, and Spanish.

The categories of gears included are: Surrounding nets, seine nets, trawls, dredges, liftnets, falling gear, gillnets, driftnets, traps, hooks-and-lines, and scoop-nets. This new second edition has added such new gear designs as a driftnet for shark (from Ghana), an elver scoop-net (from France), an Icelandic cod gillnet, and a Moroccan cockle dredge.

As with the original edition, the book covers a representative selection of the primary types of gears which are made, often, from such conventional materials as nets, ropes, and lines and which have proven profitable in commercial fisheries that operate from shore or from small boats of about 15 m length and with engines of up to 150 horsepower, and in nearshore or inland waters. This new edition stresses practical construction of the gear and its operation, utilizing drawings

or photos showing the layout and the boat and how it is maneuvered during fishing.

Also published are many useful tables and appendixes on equivalents and conversions, trade names of synthetic fibers, examples of common netting yarns, cutting rates and taper ratio, hanging ratio, and a glossary of gear terminology in all three languages, plus a guide to the abbreviations used for the gear designs.

Very well illustrated, the 224-page hardbound volume is available from the publisher for £16.00 or in North America from Bernan-Unipub, 4711-Assembly Drive, Lanham, MD, 20840 for $25.25, and it will continue to be an excellent reference for students, fishermen, educators, and others involved with fishing gear.

THE CARE AND REPAIR OF NETS

An updated second edition of the FAO's **"Mending of Fishing Nets"** by L. Libert, A. Maucorps, and L. Innes has been published by Fishing News Books Ltd., 1 Long Garden Walk, Farnham, Surrey, GU9 7HX, England. The original edition was a translation of a French handbook, and this new edition is much enhanced by a new chapter by Leslie Innes, a gear technologist from Fraserburgh, Scotland, which describes some of the specialized net repairs and techniques developed more recently ashore and on commercial fishing vessels.

As with the original, this edition is very well illustrated with 106 figures and begins by introducing the basic concepts and definitions and the materials utilized. Cutting, braiding, making single knots and meshes, inserting patches, and other net mending techniques are thoroughly described, and there is a chapter on notes on the making and mounting of net sections. The final chapter, specialized repairs on different nets, introduces commercial practices and describes repairs to gillnets, purse seines, trawls, and knotless nets. Techniques for quick repairs or net section replacement are also related. This very practical handbook is available from the publisher or, in the United States, from Bernan-Unipub, 4611-F Assembly Drive, Lanham, MD 20706-4391 for $24.00. In the United Kingdom, the price is £9.50.

The Movements and Migration of Fishes

"Mechanisms of Migration in Fishes," edited by James D. McCleave, Geoffrey P. Arnold, Julian J. Dodson, and William H. Neill, has been published by Plenum Publishing Corporation, 233 Spring Street, New York, NY 10013, as volume 14 in their NATO Conference Series IV: Marine Sciences.

The volume is divided into four primary sections: Migration in the open ocean, migration in coastal and estuarine waters, migration in rivers, and other "special" topics. A final chapter by McCleave, F. R. Harden Jones, W. C. Leggett, and T. G. Northcote summarizes various aspects of fish migration studies and makes several recommendations for future research on open-ocean, coastal, and riverine migration. Additionally, though, other authors in this volume have also proposed specific, testable hypotheses for additional research in their selected lines of research.

Considerable strides have been made in recent years in fish migration studies and in this volume, specialists from 10 North American and European nations present reviews, reports, and even some speculative views, on the mechanisms of migration in rivers and estuaries, on continental shelves, and in the oceans. Mechanisms discussed range from passive drift on water currents to behaviorally modulated drift, and active, oriented swimming. Orientation mechanisms considered include the responses of fish to temperature, food supplies, tides or ocean swell, and the earth's magnetic field. In addition, there is an interesting paper by H. G. Wallroff which reviews various long-distance orientation and migration mechanisms observed for birds and suggests that similar mechanisms of migratory orientation may be utilized by fishes, at least in cases where both classes refer to similar environmental clues.

Some topics of interest include the influence of stock origin on salmon migratory behavior, drift migrations of larval fishes in the ocean, the role of behavioral enviroregulation in fish migration, whether or how fish use inertial clues during migration, and magnetic sensitivity in the yellowfin tuna. Other papers provide a look at migration in coral reef fishes, northern Atlantic cod, and estuarine-dependent fish larvae and juveniles. Also discussed is migration and learning in fishes, modeling of migratory behavior, bioenergetic considerations in fish migrations, and measuring physical-oceanographic features relevant to fish migration. Mechanisms of fish migration in rivers are reviewed, while other papers treat homing and straying in Pacific salmon, chemical cues in salmonid homing, and physiological and behavioral determinants of chemosensory orientation. In sum, this is an excellent and thoughtful synthesis of current knowledge and work in the field which also proposes some speculative but perhaps useful avenues for future studies. The 574-page hardbound volume is available from the publisher at $95.

Reproduction, Biology, and Culture of Milkfish

The milkfish, *Chanos chanos*, is an important species which has been cultured in Asia for centuries and remains a very important source of protein. Traditionally, however, the industry has depended on stocking of farm ponds with fingerlings reared from wild-caught fry. Considerable research on the species is reflected in two recent volumes produced by the Oceanic Institute, Makapuu Point, Waimanalo, HI 96795, and sponsored by the U.S. Agency for International Development, Washington, D.C.

The first is **"Aquaculture of Milkfish (*Chanos chanos*): State of the Art,"** edited by Cheng-Sheng Lee, Malcolm S. Gordon, and Wade O. Watanabe. Written primarily for a more general audience, it presents chapters written by milkfish experts who have worked with the species for many years. Each of the chapters was refereed and revised prior to final editing. The result is a thorough and

comprehensive 284-page volume that discusses milkfish biology, genetic variation within the species, reproduction, the traditional milkfish industry (including fry capture, distribution, rearing, and growth of the fish to market size). Descriptions are given of culture practices in different nations, including aspects of pond design and management, nutrition, and a review of common diseases, and economics of milkfish culture. A final summary chapter also suggests directions for future research.

The second book, copublished by the Tungkang Marine Laboratory in Taiwan and the Oceanic Institute, is **"Reproduction and Culture of Milkfish,"** edited by Cheng-Sheng Lee and I-Chiu Liao. Also sponsored by AID, it constitutes the proceedings of a workshop held at the laboratory in April 1985, and it specifically addresses current knowledge on milkfish reproduction and the research being done to improve spawning techniques in its 226 pages.

Topics reviewed include methods for exogenous hormone administration, techniques for induced spawning in finfish developed since 1983, current technology of induced breeding of milkfish, environmental factors affecting fish (especially milkfish) reproduction, nutritional factors in fish reproduction, techniques of larval rearing used in Japan, population structure of milkfish in the Pacific, Philippine milkfish farming and research, Taiwanese milkfish culture methods and broodstock management strategy, traditional milkfish culture methods, deep-water culture systems, and a procedure for implanting a slow hormone-releasing cholesterol pellet. The volumes are both paperbound (source and price not listed).

Caribbean Invertebrates and Baja Marine Species

Publication of **"A Field Guide to Caribbean Reef Invertebrates"** by Nancy Sefton and Steven K. Webster has been announced by Sea Challengers, 4 Somerset Rise, Monterey, CA 93940. This colorful handbook is a special publication of the Monterey Bay Aquarium Foundation and provides color photos of about 200 of the most common and observable invertebrates (plus 14 algae and 2 seed plants) of the Caribbean region. Also included are data on the specific habitats where the species are found, along with information on their natural history. Where possible, the creatures have been identified to the species level. A glossary will be helpful for nonscientists.

The authors begin with a discussion of the coral reefs of the Caribbean Sea and the region's geology, and then discuss reef structure and zonation, and growth, reproduction, and nutrition of corals. That is followed by introductory information on each of the major invertebrate phyla: Porifera, coelenterata, ctenophora, bryozoa (ectoprocta), annelida, platyhelminthes, arthropoda, mollusca, echinodermata, chordata (tunicates), and members of the plant community—red, green, and brown algae, and the seed plants.

That section is followed by full-color photographs of the individual species themselves and a brief notations on their identification and natural history. The photographs are excellent and the manual should be of interest and use to those scuba diving or working in Caribbean marine environments with coral reefs. Indexed, the 112-page volume is sold by the publisher for $19.95.

In addition, Sea Challengers has produced the second edition of **"Marine Animals of Baja California,"** subtitled "A Guide to the Common Fishes and Invertebrates," and authored by Daniel W. Gotshall. The volume describes 150 species of fish and 65 species of invertebrates commonly found in the shallow waters of the Baja California peninsula and Islas de Revillagigedo. It would also be useful for identifying shallow water fishes along much of the coast of Central America and the Islas de Galapago. Fishes excluded are the tiny ones like gobies, tube blennies, and clingfish that are not often encountered by sport divers.

The author again stresses the use of the color plates and the pictorial keys to identify the fishes and invertebrates. The illustrations are excellent, and data is provided on their maximum known size, habitat, geographic range, plus identifying characters that are usually noted while underwater. Families added to this second edition include the requiem sharks, machetes, herrings, needlefishes, pipefishes and seahorses, and mullets. A bibliography is provided for those wanting further information on fishes of that area. Indexed, the 112-page paperbound volume is available for $17.95 plus $1.85 shipping.

Ocean Disposal and Marine Pollution

Selected papers from the sixth international Ocean Disposal Symposium, edited by Douglas A. Wolfe of NOAA's National Ocean Service, have been published as **"Plastics in the Sea,"** a special issue of the *Marine Pollution Bulletin*, 18(6B):303-365, by Pergamon Press, Headington Hill Hall, Oxford OX3 OBW, England. Publication price is DM20.00 or U.S.$10.00 in the Americas and £5.00 in the United Kingdom. The symposium was held at the Asilomar Conference Center, Pacific Grove, Calif., on 21-25 April 1986.

Contributions provide a very handy review of the effects of litter pollution from ships on such marine species as sea turtles, albatrosses and shearwaters, seals, gannets, and others. Discussed are the sources, quantities, and distribution of persistent plastics in the seas, patterns in the abundance of pelagic plastic and tar in the North Pacific, biological effects of lost and discarded plastic debris, and litter pollution from ships in the German Bight. The problem is international in scope and two of the papers address potential remedies (i.e., legal strategies for international action). Indexed by author and subject, the issue is available from the publisher.

Editorial Guidelines for the *Marine Fisheries Review*

The *Marine Fisheries Review* publishes review articles, original research reports, significant progress reports, technical notes, and news articles on fisheries science, engineering, and economics, commercial and recreational fisheries, marine mammal studies, aquaculture, and U.S. and foreign fisheries developments. Emphasis, however, is on in-depth review articles and practical or applied aspects of marine fisheries rather than pure research.

Preferred paper length ranges from 4 to 12 printed pages (about 10-40 manuscript pages), although shorter and longer papers are sometimes accepted. Papers are normally printed within 4-6 months of acceptance. Publication is hastened when manuscripts conform to the following recommended guidelines.

The Manuscript

Submission of a manuscript to *Marine Fisheries Review* implies that the manuscript is the author's own work, has not been submitted for publication elsewhere, and is ready for publication as submitted. Commerce Department personnel should submit papers under a completed NOAA Form 25-700.

Manuscripts must be typed (double-spaced) on high-quality white bond paper and submitted with two duplicate (but not carbon) copies. The complete manuscript normally includes a title page, a short abstract (if needed), text, literature citations, tables, figure legends, footnotes, and the figures. The title page should carry the title and the name, department, institution or other affiliation, and complete address (plus current address if different) of the author(s). Manuscript pages should be numbered and have 1½-inch margins on all sides. Running heads are not used. An "Acknowledgments" section, if needed, may be placed at the end of the text. Use of appendices is discouraged.

Abstract and Headings

Keep titles, heading, subheadings, and the abstract short and clear. Abstracts should be short (one-half page or less) and double-spaced. Paper titles should be no longer than 60 characters; a four- to five-word (40 to 45 characters) title is ideal. Use heads sparingly, if at all. Heads should contain only 2-5 words; do not stack heads of different sizes.

Style

In style, the *Marine Fisheries Review* follows the "U.S. Government Printing Office Style Manual." Fish names follow the American Fisheries Society's Special Publication No. 12, "A List of Common and Scientific Names of Fishes from the United States and Canada," fourth edition, 1980. The "Merriam-Webster Third New International Dictionary" is used as the authority for correct spelling and word division. Only journal titles and scientific names (genera and species) should be italicized (underscored). Dates should be written as 3 November 1976. In text, literature is cited as Lynn and Reid (1968) or as (Lynn and Reid, 1968). Common abbreviations and symbols such as mm, m, g, ml, mg, and °C (without periods) may be used with numerals. Measurements are preferred in metric units; other equivalent units (i.e., fathoms, °F) may also be listed in parentheses.

Tables and Footnotes

Tables and footnotes should be typed separately and double-spaced. Tables should be numbered and referenced in text. Table headings and format should be consistent; do not use vertical rules.

Literature Cited

Title the list of references "Literature Cited" and include only published works or those actually in press. Citations must contain the complete title of the work, inclusive pagination, full journal title, and the year, month, volume, and issue numbers of the publication. Unpublished reports or manuscripts and personal communications must be footnoted. Include the title, author, pagination of the manuscript or report, and the address where it is on file. For personal communications, list the name, affiliation, and address of the communicator.

Citations should be double-spaced and listed alphabetically by the senior author's surname and initials. Co-authors should be listed by initials and surname. Where two or more citations have the same author(s), list them chronologically; where both author and year match on two or more, use lowercase alphabet to distinguish them (1969a, 1969b, 1969c, etc.).

Authors must double-check all literature cited; they alone are responsible for its accuracy.

Figures

All figures should be clearly identified with the author's name and figure number, if used. Figure legends should be brief and a copy may be taped to the back of the figure. Figures may or may not be numbered. Do not write on the back of photographs. Photographs should be black and white, 8 × 10 inches, sharply focused glossies of strong contrast. Potential cover photos are welcome, but their return cannot be guaranteed. Magnification listed for photomicrographs must match the figure submitted (a scale bar may be preferred).

Line art should be drawn with black India ink on white paper. Design, symbols, and lettering should be neat, legible, and simple. Avoid freehand lettering and heavy lettering and shading that could fill in when the figure is reduced. Consider column and page sizes when designing figures.

Finally

First-rate, professional papers are neat, accurate, and complete. Authors should proofread the manuscript for typographical errors and double-check its contents and appearance before submission. Mail the manuscript flat, first-class mail, to: Editor, *Marine Fisheries Review*, Scientific Publications Office, National Marine Fisheries Service, NOAA, 7600 Sand Point Way N.E., Bin C15700, Seattle, WA 98115.

The senior author will receive 50 reprints (no cover) of his paper free of charge and 50 free copies are supplied to his organization. Cost estimates for additional reprints can be supplied upon request.

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